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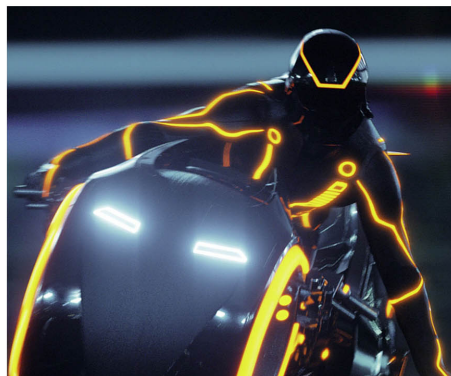
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Visions of the Hereafter

image

By Jody Duncan

An unusual aspect of director Clint Eastwood's *Hereafter* is that its only large-scale action sequence, rather than occurring at the climax, actually opens the film, which then segues into a quietly personal and thoughtful story about three characters in search of something or someone lost to the hereafter. In the wake of a near-death experience after drowning, French journalist Marie Lelay (Cécile de France) searches for answers. In London, young Marcus (Frankie and George McLaren) searches for a connection to a twin brother recently killed. The third intertwining storyline follows Gean (Matt Damon), a lonely man and a reluctant psychic whose ability to communicate with deceased loved ones has left him searching for a normal life and relationship.

The eight-minute action sequence that opens *Hereafter* has a tsunami sweeping over an unnamed Indonesian resort town, flooding streets and destroying buildings on a massive scale. The tsunami wave and its impact represented 86 of *Hereafter*'s 169 effects shots, while the remainder involved digital makeup, environmental work, effects animation and visions of the hereafter. Visual effects supervisor Michael Owens, on whom Eastwood has relied for his films' visual effects needs since the 2000 space adventure *Space Cowboys*, oversaw all of *Hereafter*'s effects.

From the outset, Eastwood, Owens and producer Robert Lorenz had determined that they would realize the tsunami entirely through computer generated effects, rather than attempt to shoot dump-tank or other practical water gags. "Clint and Rob and I had several discussions about it," recalled Michael Owens, "and we just decided to do it all with visual effects, and not to try to do any of it for real. We would stage some foregrounds on location, but the midgrounds and backgrounds would always be virtual."

Owens began by storyboarding the sequence with storyboard artist Peter Rubin, and those storyboards were then turned over to Scanline, the visual effects company assigned the show's effects. Founded in Germany, and now established in Los Angeles, Scanline had earned a reputation for simulating photorealistic fire and water through its Flowline software, for which the company won a technical achievement Academy Award in 2008. "I went into the project with an open mind," said Owens, "and I looked at everybody's reels. But the only companies that showed me photoreal water in photoreal settings were ILM, Scanline and Digital Domain. All the other reels showed me water in fantasy-oriented movies, and so the water had a fantasy feel to it. Scanline had been working on photorealistic water for years, and had done fantastic work on *Twister*. Even though this was going to be the first show for the L.A. studio as sole vendor, it made sense to go with Scanline, and I'm very happy that we did."

"We have a passion for this type of work," added Scanline visual effects supervisor Stephan Trojansky, "and so it became a core of our company. Other companies develop water because it is needed for a particular show, but then they drop it when that show is over." In contrast, Scanline has never stopped developing Flowline, and is constantly improving and upgrading the software. "A few years ago, we passed the threshold of being able to create realistic water at any scale, in virtually any type of scene or situation. At that point, the challenge became how to make the

simulation run faster and how to get better integration. In-stead of having to wait a week to get a new simulation, now we can run new iterations a couple of times per day. That gave Michael Owens the freedom to really design the shots. In fact, he said to us, ‘I can finally be an art director on these water shots, and not just a victim of the simulation.’”

Scanline initiated the *Hereafter* project by translating Michael Owens’ storyboards to previz. But before any of that previz work had been started, the show’s unusual production schedule—which had been determined by Matt Damon’s narrow availability—mandated that the filmmakers shoot water tank material at Pinewood Studios in London. “We shot this foreground stuff in the greenscreen water tank at Pinewood right after I finished the storyboards,” Owens recalled. “So it was a little scary because we were shooting out of order. But Clint said, ‘Let’s just try it, see what happens, and if we need to, we can come back.’ Clint let me handle that whole day of shooting. I shot Cécile de France and a couple of other people in the tank, just to give us something to work with. We shot both underwater and surface stuff, and then I cut it together and started working with Scanline to create the whole sequence as a 3D previz.”

The previz clarified the effects work, which would range from wire removals or adding a little bit of CG set enhancement to an otherwise live-action shot to full CG shots of the tsunami rushing through entirely virtual environments. “Often in a show, you have one type of setup that you develop or one look-dev that you do,” noted Stephan Trojansky, “and then you just apply that to every shot in your sequence. On this show, almost every shot had its own technique and approach. There were about eight full CG shots, where the entire environment and the main character, the crashing buildings, the wave, the debris floating in the water, cars crashing into buildings, everything was CG. Those were some of the most challenging shots, of course.”

Owens and Scanline visual effects supervisor Bryan Grill relied on the 3D previz to help them plan effects shots when they accompanied the production to Lahaina, a picturesque town on Maui, where Eastwood and his crew shot the sequence’s live-action. Grill oversaw photography and surveys of the main street, which the art department had redressed with new storefronts and colorful marketplace kiosks to give it a more Indonesian flavor. The imagery and data would enable Scanline to re-create and extend the set digitally for shots of the tsunami flooding the main street. “We had just a small, one-block section of the main street in Lahaina,” stated Grill, “and we had to build that out to about a mile stretch, which is the length Marie travels when she is caught in the tsunami. We shot HDRI still photography of the main street set, and then we also photographed other streets to give us some variety. We pretty much went through all of downtown Lahaina and shot anything that we thought looked interesting so we wouldn’t have to reuse everything from the main street throughout the whole sequence. We also did a lidar scan of pretty much the whole main street of Lahaina.”

In addition to capturing pre-tsunami live-action of Marie shopping in the marketplace, production shot people running down the Lahaina main street, as if escaping the oncoming tidal wave. The filmmakers also shot additional foreground material of Cécile de France in the Maui surf. “Just before we got to



Hawaii,” recalled Owens, “Clint said, ‘The tank shoot went well, but there’s just something about an actress in a greenscreen tank that isn’t quite as real as the real thing.’ His idea was to go out and shoot some extra stuff in the ocean while we were in Hawaii. So after we did the street shooting, we took underwater cameras, put them on surfboards and went out in the ocean and shot a bunch of stuff with Cécile de France and this little girl she is next to when the wave hits her. It actually worked very well. The lighting was completely wrong, so we had to work hard to rearrange that; but the action and momentum were great. The surf was moving up and down and the actress and the little girl could feel it, so it made for really great footage. We used more of the tank stuff, just because we had more of it, but we used quite a bit of that real ocean stuff, as well, incorporating it into the virtual water.”

The sequence begins with Marie shopping in the outdoor market, live-action shots enhanced with digital set extensions and altered, more dramatic backgrounds by Scanline. The action then cuts to Marie’s boyfriend, Didier (Thierry Neuvic), in their hotel room. Hearing a strange roar, Didier goes to the balcony overlooking the beach and sees the ocean receding from the shoreline to form a massive wave. The shot is the first big reveal of the CG water, simulated in Flowline and rendered in V-Ray to look impeccably photorealistic. “V-Ray and Flowline play very well together,” remarked Scanline CG supervisor Danielle Plantec. “Flowline can actually transfer information about the fluid sim out to the renderer, so we’re able to use standard shaders just as you would for any hard surface; but since we’re dealing with a fluid, we also go into a lot of additional detail for surface properties and things like spray and foam. Specular properties, the little shines and glints that we get off of the water, are also handled through Flowline. In the old days, people would texture and kind of map on the look, but this simulation provides a lot of that look for free. It takes the motion of the fluid and actually generates foam and bubbles.” The balcony reveal shot also featured a wave-tossed CG ship, modeled and rendered by Scanline.

What follows is an epic wide shot of the tsunami coming ashore, crashing into a beachfront resort hotel. To determine the look of the ‘money shot,’ the Scanline team sampled imagery of the 2004 Thailand tsunami that had been captured on cell phones. “From those images,” said Stephan Trojansky, “we got a sense of how the wave would move from the ocean and crash into the resort, taking out buildings and overtaking people running away.”

The first step was to define the shape and choreography of the wave itself. “Before we got into any of the destruction of the environment,” said

Though Hereafter, like most of director Clint Eastwood’s films, is a quiet, character-driven piece, it opens with a dynamic eight-minute visual effects sequence in which a tsunami destroys a beachfront resort town in Indonesia. At the earliest stages of planning the film, Eastwood, producer Robert Lorenz and visual effects supervisor Michael Owens made the decision to realize the tsunami entirely via computer generated effects, rather than attempt dump-tank gags or other large-scale practical water effects. Owens awarded the show’s effects shots to Scanline, which had earned a stellar reputation for creating photoreal water simulations in films such as 2012 and Poseidon.



Wide shots near the beginning of the 86-shot sequence reveal the massive wave’s impact with a beachfront hotel. Scanline visual effects supervisors Stephan Trojansky and Bryan Grill and their team referenced images of the 2004 Thailand tsunami to determine the look of the wave’s destructive interaction with structures in its path. Production provided Scanline with an aerial plate of a real hotel, but the visual effects artists ultimately replaced

Danielle Plantec, “we had to get the wave exactly as Michael Owens wanted it. So the first thing we did was a very low-rez simulation to figure out the shape, speed and timing of the wave. We did a lot of back and forth with Michael to get those timings and all the beats worked out.”

Once the wave behavior had been determined in low-resolution simulations, Owens and the Scanline team began producing iterations of its impact on the environment. Though production had shot a plate for the hotel wide shot, the team wound up replacing virtually everything in that plate to create a more controllable computer generated environment. Scanline perfectly matched the structures and poolside area that were in the plate, and detailed it with CG collapsing umbrellas, chaise lounges, wine glasses, pool toys, jet skis, falling palm trees and every other accouterment of a hotel setting—much of which would show up later in the sequence as debris in the raging water. In the end, the shot was 100-percent digital.

To create interaction between the CG environment and the wave, Scanline ran rigid body dynamics simulations in conjunction with its water simulation. “The wave would come in,” related Plantec, “and hit objects that were sitting in 3D on our little digital set; and as the wave hit an object, that object would start to simulate, as well, picking up on the velocities and the motion of the water and then moving with the water. The rigid body sim would have some objects going under the water, and some floating on top, depending on how heavy they were. Some palm trees would snap and break, some would just be knocked over, and some would resist a little bit more. And then on top of that, we’d get the soft-body dynamic of the leaves flapping in the wind or falling.”

Likewise, Scanline ran a simulation for the destruction of the hotel, which the team built in CG much as a construction crew would build a physical structure, first erecting the skeletal understructure and then building out from there, down to every shingle on the roof. “By building it that way,” explained Plantec, “the simulation would break the structure in the weaker areas when it was subjected to the pressure of the wave. So the shingles would tear off the roof more easily and faster than other parts; and then you’d see whole pieces of the structure break off and get carried away in the wave. All of that was set up in the simulation. The base fluid would control how the rigid bodies were being destroyed, and then we could rerun the simulation at a higher resolution, with all the spray and mist, and with the rigid bodies added into it. Michael chose not to show this shot to Clint until it was at that stage and had all of that included. Fortunately, Flowline allowed us to turn the shot around very quickly every day; and so we were able to do many iterations and get it just right before Clint saw it.”

The sequence continues with a shot of people in the street running from the oncoming tsunami wave—not yet visible in the background from this vantage point. Rather, all one sees are palm trees being knocked over in the distance. The crew dubbed it the ‘Jurassic Park’ shot, due to its resemblance to a shot of trees being downed by an unseen T-rex in the film by Steven Spielberg, one of *Hereafter*’s executive producers.

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The water swiftly reaches the street, overtaking running people, including Marie and the little girl she has pulled along with her. In addition to Cécile de France and the young performer, production had shot extras running through the street. But the crowd was so thick, the plates left little room for the tsunami wave; and so Scanline wound up having to remove most of the running extras in the plate. “We had to do extensive work to create open space for the water,” noted Bryan Grill. “There was this small street with all the vendors and kiosks; and by the time you added 30 people running down the street, it was completely filled. You couldn’t see down the street anymore, which meant you wouldn’t have been able to see the wave coming. So we had to clean out almost all of the real people, clean out part of the street, rebuild it, and then put in CG people, with just a few of the live-action people in the foreground. That was no easy task.”

To create digital characters being swept away by the wave for this and subsequent shots, Scanline captured motion capture material at Giant Studios. The motion capture stage was equipped with zero-gravity wire rigs that performers were attached to at the waist, enabling them to perform floating, swimming and thrashing movements of characters in rushing water. “They would move them through the studio on wires so we could get all these reactions of them being slammed into things and pushed along by the water,” said Grill. “We also had a few shots where we used pure keyframe character animation.”



Journalist Marie Lelay (Cécile de France), shopping in an outdoor marketplace near the resort, grabs hold of a little girl and runs from the oncoming wave. Production shot all the live-action for the sequence in Lahaina, Hawaii – a picturesque village on the island of Maui – including shots of de France and extras running down a dressed Lahaina street. To render the onrushing wave visible in the busy background, Scanline artists had to paint out obscuring extras in the foreground, and then rebuild the set and add digital characters being overtaken by the water. For digital characters interacting with water throughout the sequence, Scanline conducted a motion capture shoot at Giant Studios, attaching performers to zero-gravity rigs to enable them to perform floating, swimming and thrashing movements.

Eastwood maintained focus on the character of Marie, in the foreground, as the wave carries her nearly a mile through the disintegrating street. Among the major challenges of the sequence was integrating the foreground footage of Cécile de France in the Pinewood tank or the ocean with the simulated water surrounding her in the midground and backgrounds. “On past shows where we had done CG water,” Stephan Trojansky noted, “the shots had been fully CG, so we could completely control the look and movement of the water. But on this, we had to match our water to real water. We would have a shot of the actress in the ocean, with particular splashes and movement of the water, and we had to integrate our CG water with that and turn it into a shot of her in the rushing wave. The problem was how to create a seamless transition between the water in the plate and the simulated water.”



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To create that seamless transition, Scanline artists first manually tracked the motion and speed of the live-action water, and then used that data as a constraint in the simulation engine at the point where the real water transitioned to digital water. The result was CG water that behaved in a manner identical to that of the real water in the plate. “From there,” Trojansky stated, “we made a series of soft transitions to all-CG water, which could do its own thing because it was further from the real water. It was a process that took a lot of reiterations, but it worked.”

The team also had to add in the traveling motion of Cécile de France within the rushing wave, as she had been relatively static in both the ocean and the water tank footage. “When she was shot in the tank or the ocean,” Trojansky explained, “she could only swim so fast and travel only so far. So we had to match her and the water around her to the velocities and movements of a rushing tsunami moving 30 miles an hour down the road.”

The wave crashes into structures, telephone poles, parked vehicles and trees as it rushes through the mile-long street environment, all of which Scanline built in both Nuke and 3dsMax. “The whole environment lived in two places and matched perfectly,” explained Bryan Grill, “so that, depending on the type of work we needed to do, we could do it in 2D, 2½D projections, or in a complete 3D render. We were able to pick and choose between those options on a shot by shot basis. For example, where buildings had to be destroyed by the wave, we did full 3D, complete with rigid body dynamics, full-on smoke and all of that. Right next to that could be a 2½D projected building, and beyond that a matte painting. Where we needed to do full 3D for interaction and destruction, we did; and where we didn’t, we didn’t.”

Replicating and extending the street environment required the building of nearly 60 CG structures. Scanline also built a huge library of CG debris consisting of large-scale items such as cars and

broken chunks of buildings, as well as smaller objects from the outdoor marketplace. “We matched everything that had been in the large farmer’s market set,” noted Danielle Plantec, “so there were masks and flowers and leis, all driven by the tidal water. It was quite an interesting challenge to get the interaction between the debris and the water. We could drive everything through the simulation, and we usually did that for smaller pieces like items from the market or pieces of construction debris. Larger pieces of debris were more often hand-animated, just so Michael Owens could art-direct them.”

Integration of the digital water, characters, set pieces, debris and the foreground tank and ocean footage throughout the sequence was an enormous task that fell largely to Scanline composite supervisor Joe Farrell. “This was the most complicated and difficult compositing job I’ve ever seen,” stated Farrell, “and it was a different kind of work than what we normally do. Sometimes you can get away with being kind of mechanical in the way you approach a composite: ‘Here’s a robot, the dust needs to go this high, blah, blah, blah.’ This job was: ‘We need this shot to look completely real, even though there’s virtually nothing in it that’s real. So just run with whatever you can possibly come up with on your own to make that shot work.’” Given that mandate, Scanline hired a team of compositors with reputations for being not only the best in the business, but also independent and self-directed. “We needed people who could work by themselves, who could handle being given free rein to come up with things on their own. If they needed to shoot something, they’d just go out with a camera and shoot it, and then use that in the composite.”

The sequence continues with Marie losing her grasp on the little girl, and then being pulled underwater when her skirt is caught on a heavy, sinking cart. The shots of Marie underwater, trying to disentangle her skirt from the cart, were among those photographed in the tank at Pinewood early in production, as was the following shot of her surfacing and grabbing hold of a fallen tree branch. To justify the flat studio lighting in the tank shot of Marie holding onto the branch, Scanline artists designed the lighting for the preceding shots so as to put the character in shadow in that area. “Essentially,” stated Danielle Plantec, “we worked backward from the lighting situation we had in our element to make that flat lighting work.”

Having grabbed onto the tree branch, Marie appears to have survived the tsunami and found safety; but within moments, a car carried by the rushing water smacks into her. The following all-CG underwater shot of the unconscious woman floating slowly past camera was designed to be much more surreal than all the other shots in the highly realistic sequence, with every detail carefully art-directed by Michael Owens. “After all the noise and action of the preceding shots,” recalled Owens, “this is where everything suddenly slows down and gets very quiet—because this is the moment she drowns and dies.”

The camera moves in on the floating, unconscious Marie—a digital double that Scanline built from a full scan of Cécile de France and a texture shoot. “We get pretty close to this digital double,” noted Bryan Grill. “She fills about a quarter of the screen.”

The shot also featured simulated bubbles and particulate matter, and penetrating rays of sunlight illuminating the underwater scene. “In reality,” Michael Owens observed, “that type of underwater environment would be very dark and murky, with all the debris and mud and other matter being

churned up by the tsunami. But we took this artistic license of illuminating the character and surrounding her with art-directed bubbles and debris.”

With the stopping of her heart, Marie experiences a vision of the hereafter—the first of the film’s several hereafter shots. No visual in the film required more exploration than did the look of the hereafter. “It wasn’t terribly complicated, technically,” Owens remarked, “but artistically, it was quite difficult. We knew that if we showed too much, the audience would not buy it. But they also would not buy it if we showed too little. We were always trying to ride that line. In the end, Joe Farrell was the guy who nailed the look of the hereafter. He was just brilliant in coming up with all of this interesting, eerie hereafter stuff.”

“Clint came in with no particular preconceived ideas about the look of the hereafter,” observed Joe Farrell. “The only brief we had from him was that he did not want it to be dark or scary. Michael had plenty of visual thoughts, though, and we spent two or three months just throwing out ideas and doing research. One of the interesting things I found is that there are some very common themes in the stories of people who have had near-death experiences. One was a sense of seeing everything in 360 degrees, as if the person is aware of everything around him. Other common elements they described were a sense of floating, a sense of beings present, and a sense of incredibly bright light, but not hurt-your-eyes physical light.”

With those descriptions in mind, Farrell began playing with imagery in the computer, starting with footage of the aliens emerging from the mothership in *Close Encounters of the Third Kind*. “I treated the *Close Encounters* footage as if it was shot with a very long shutter lens,” explained Farrell, “taking images 50 frames back and 50 frames forward and doing a long time-lapse. I did all kinds of crazy things to that footage. We put that in the previz as temp imagery, and Michael loved it.”

Having determined, in general terms, the look of the visions, Owens, Farrell and director of photography Craig Kief conducted a greenscreen shoot in which they photographed people of various ages in smoke, using a RED camera. “We shot about 50 extras during a one-day greenscreen shoot in Hollywood,” recalled Farrell. “We put a big 20K light behind them all, and then shot straight into that while they were ramping the light up and down so that we’d get these really intense rim lights. I also had them pull focus and move the camera around. I think all of this weird stuff freaked out the DP a bit at first; but he had a blast doing it, because he was able to let down his guard and let the camera do whatever it wanted.”



The wave sweeps up Marie and carries her nearly a mile through the flooding streets of the town. After the initial wide shots of its impact at the shoreline, Eastwood moved in to reveal the tsunami as it was experienced by Marie, keeping his camera focused on her in the foreground throughout the sequence. To capture that foreground material, production shot Cécile de France in a water tank at Pinewood Studios prior to principal photography. While in Hawaii, Eastwood orchestrated an impromptu shoot to augment the tank material with more realistic ocean

footage, filming de France in the surf off Lahaina with cameras mounted to surfboards.

From there, Farrell began building a 3D virtual hereafter space in Nuke, into which he would place the characters from the greenscreen shoot. “We explored what that environment should be right up to the time we were done with the show,” remarked Michael Owens, “because the look was rather elusive. Based on afterlife descriptions and stories, the environment couldn’t be entirely tangible—and yet it had to be tangible enough to give the audience a clear visual.”

Farrell’s first stab at the environment was to manipulate parts of the CG Lahaina street set to create strange, but still identifiable photocopies of specific buildings. As the look evolved, however, the environment became less defined, and more ethereal. “I started with the building models,” Farrell said, “and then hacked them up and treated them so much that you can’t really tell what the environment is. So the buildings are still there in the final shots, but you would never know it. In the end, what we wanted in the environment was a sense of depth going out to a horizon, which Michael felt was very important, so that the beings wouldn’t appear to be in a void.”

To define the space, Farrell incorporated a ground plane and a warped kind of ceiling plane overhead. “Even though the shots looked quite vague and ethereal,” stated Farrell, “you could still see that there were two planes—this ground plane below and the water plane above. That created an interesting effect, as if Marie was between two worlds.”

George’s psychic visions of the hereafter are slightly different than Marie’s first-person experience. “She is actually dead, and there in the hereafter,” explained Owens, “but George is just getting psychic flashes of it. He does a reading for the little boy Marcus, for example; and, in the vision, he not only sees the twin who has passed on but also the twin he’s doing the reading for. His visions are more like third-person montages, rather than the direct vision of the person experiencing the afterlife; and so we came up with some subtle variations on the effect for the George flashes.”

“We actually contemplated making them noticeably different,” Farrell added, “but we decided that it would have disjointed the whole concept of the movie. So we ended up making them just slightly different. The quality of the light is a little different than Marie’s vision, and there are subtle color differences, as well.”



To create a seamless transition from the water in the tank and ocean foregrounds to CG water – simulated through Scanline’s Flowline software – the visual effects team first tracked the speed and motion of the water in the live-action plates, and then used that data as a constraint in the simulation engine so that the adjacent CG water would behave in an identical manner. Scanline also filled out the ocean and tank plates with CG environments, producing destruction effects by running rigid dynamics simulations in conjunction with the water simulation.

Marie's one-minute vision begins to recede, and the camera transitions to the POV of rescuers who have pulled her lifeless body out of the water and are attempting to resuscitate her. The shots reveal a battered and bruised Marie, all of which was done as a digital makeup effect to accommodate Clint Eastwood's expeditious shooting style. Bryan Grill, who had worked with Eastwood and Michael Owens on *Flags of Our Fathers*, had a first-hand understanding of Eastwood's preference for digital makeup effects. "We were doing a lot of practical makeups throughout that show, especially at first," Grill recalled, "and they took up a lot of time, as they always do. But Clint started to catch on that we could do bruising and scratches and blood digitally. Doing all of that in post was a perfect solution for him, because he would rather be rolling film than waiting around on the set. The other problem with on-set makeup effects is dealing with continuity. With both the tank footage and the ocean footage of Marie being shot out of order, we mixed and matched elements to get the best performance we could for each shot in the sequence. By doing it all in post, he was free to do whatever he wanted with his cuts and so on, without having to be trapped into what was shot on set."

Marie is eventually revived, and the action cuts to the next day, when she searches the shattered remains of the beach town for Didier. The production art department had built a relatively small aftermath set in Hawaii, made up of debris and a wrecked boat. Scanline extended the small set with an expansive CG matte painting that depicted widespread destruction.

With the reunion of Marie and Didier, the sequence comes to an emotional close that sets the tone of the film's remaining 116 minutes. "Even though the tsunami sequence is an action sequence," Stephan Trojansky commented, "it's very emotional. There's all this destruction happening, but the focus is on the human aspect of it. That's because this movie was in the hands of someone who wanted to tell human stories. Michael Owens told us from the beginning that this sequence wasn't about creating effects shots, and wasn't about this tsunami. It was part of the story, but it had nothing to do with what this movie actually wanted to say."



Marie drowns in an all-CG shot that was the most surreal of those in the otherwise highly photorealistic sequence. Michael Owens art directed every detail of the shot, including the quantity of simulated bubbles and particulate matter in the water and the quality of the rays of sunlight illuminating the underwater scene. Scanline made use of a full body and head scan of Cécile de France and conducted its own texture shoot to build the digital-double Marie for the shot. As Marie's heart stops, she experiences a vision of the hereafter that haunts her throughout the show.

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Legacy System

image

By Jody Duncan

In 1982, animator, writer and director Steven Lisberger and Walt Disney Pictures collaborated on a quirky but technologically ambitious movie, *TRON*, about a genius computer programmer named Kevin Flynn (Jeff Bridges) who is digitized and transported into the computer world by a malevolent master control program. Within the digital realm, Flynn fights for his survival in a series of gladiatorial games and ultimately outwits the master control program to find his way back to the real world.

Just as many science fiction films of the 1950s reflected society's anxieties over the emergence of nuclear power in the post-Hiroshima era, *TRON* explored a collective unease that accompanied developing computer technology. More significant than its underlying themes, however, *TRON* – with its simple computer graphics grids and vehicles -- was the first film to hint at the potential of computer generated imagery as a visual effects tool in filmmaking.

Larry Elin one of *TRON*'s technical pioneers, recognized the film's historical significance at the time it was released, observing: "The nice thing about computer-generated animation is that there's really no end to the possibilities for it. The technology is literally a fetus. *TRON* is going to be thought of as the maternity ward of computer graphics in entertainment."

Elin's prediction was accurate. Twenty-eight years later, aficionados of today's exceptionally sophisticated, photorealistic computer generated visual effects point to *TRON* as the launch of digital technology in filmmaking. The temptation to go back to the world of *TRON* and see what filmmakers could do with current, state-of-the-art CG was not one that the Disney studio could resist—and the aptly named *TRON: Legacy* was born.

With Lisberger participating in the sequel as producer, Disney hired director Joseph Kosinski to helm the production and Digital Domain's Eric Barba—with whom Kosinski had worked first on the 2006 commercial for the *Gears of War* videogame—to provide overall visual effects supervision. Digital Domain was aided and abetted in the effort by its Vancouver office, which delivered 180 shots over multiple sequences, as well as partner studios, including Mr. X, Ollin Studio, Prime Focus and Whiskytree.

Kosinski had seen the original *TRON* as a child, watching it on VHS at home. "I remembered it as being completely unique and stunning visually," observed Kosinski, "and, of course, technically groundbreaking. And so, when I was approached to do this film, I knew we'd have to set the bar pretty high and make our film just as visually unique and technically groundbreaking. There were big shoes to fill."

Kosinski began working on the story with producer Sean Bailey, co-producer Justin Springer, *Lost* writers Adam Horowitz and Eddie Kitsis, and screenwriter Richard Jeffries after signing onto the project in summer 2007. "It was a very collaborative process," said Kosinski. "We developed the story over a period of a year and a half to get the script to the point where we could shoot it. It wasn't just

a matter of writing this new film. We had to preserve the story from *TRON*, and bring back those original characters, most notably Kevin Flynn, played by Jeff Bridges. We also had to build the interim 28 years between 1982 and 2010, and then take off from there with a new story.”

TRON Legacy’s back story has Kevin Flynn continuing his technological research and making frequent forays into the digital world, finally disappearing into that world for good in 1989, leaving behind a son. “We pick up the story in 2010 when his son, Sam Flynn, gets a clue as to where and why his father disappeared,” explained Kosinski. “He follows that clue back to Flynn’s Arcade, discovers his father’s secret laboratory where he was conducting experiments, and finds himself pulled into the world of Tron, where he tries to find his father and get back home.”

As Kosinski, the producers and writers created the narrative, Disney requested that the filmmakers also resolve technical issues. The film’s computer environments and vehicles would be highly complex, stylized and sophisticated—not an easy task, by any means, but still the kind of work Digital Domain and the other vendors had been doing for years. The bigger effects challenge would be the character of Clu, a program written by Flynn in the 1980s that has since evolved its own independent agenda. In the original film, Clu had made a brief appearance as a type of reconnaissance vehicle, searching the computer world for evidence of programming chicanery. In the new film, Clu would serve the antagonist role in the narrative, and would be portrayed by Jeff Bridges—but appear as the actor looked at the age of 35.

The task put before Eric Barba and his team at Digital Domain was akin to, but also the inverse of what they had achieved for David Fincher’s *The Curious Case of Benjamin Button*. Barba and his colleagues had won the Academy Award for best visual effects that year for creating a series of astonishingly lifelike digital heads representing actor Brad Pitt in advanced stages of aging. For *TRON: Legacy*, they would create the Jeff-Bridges-at-35 digital Clu, whose performance would be driven by the actor himself via ‘e-motion capture’ technology.

As challenging as the Benjamin Button effects had been, the effects artists had benefited from the fact that nobody knew what an 85-year-old Brad Pitt would look like. In contrast, everyone knew what a 35-year-old Jeff Bridges looked like, which meant that audiences would recognize immediately if the digital character failed to re-create the actor in every detail.

The character of Clu was so crucial to the film that Disney asked to see a proof-of-concept test prior to fully committing to the project. Since Disney intended to release the film in full 3D, the test would also clarify the demands of shooting stereoscopic live-action. Kosinski shot footage for the stereoscopic test in January 2008. Digital Domain incorporated the visual effects and animation, and Disney showed the final test at Comic-Con the following summer. “The test was not a scene from the movie, actually,” explained Kosinski. “It was a scene that I came up with that included a little bit of a lightcycle race, just to show the studio the tone and look of this world, as I saw it. I also got Jeff Bridges to do a small part in it, so we could hint at this idea of him playing two characters. It was a way for me to show the studio what I was thinking; but it turned out to be a nice little piece of marketing, as well. It allowed us to test the waters and see if people were interested in seeing another chapter in the *TRON* story—and it turned out that they were. The reaction at Comic-Con that first year was a nice bit of momentum.”

With the production's greenlight, an art department headed by production designer Darren Gilford moved into offices at Digital Domain to facilitate a closer-than-usual collaboration between those developing concepts and those tasked with realizing them. "I wanted it to be a fully paperless digital studio from the beginning," Kosinski observed. "A big reason I gave Darren Gilford the job was that he is completely fluid in doing design digitally, which allowed us to share files between artists very quickly. It also ensured that when it came to the videogame or toys or other things that would spin out of the film, we could hand over the actual digital assets to ensure that the reproduction would be as accurate as possible."

Even with the efficient paperless approach, and with the art and visual effects teams working in proximity, Kosinski—who has a background in architectural design—knew that conceptualizing the film's vast computer world from the ground up would be the single most challenging and labor-intensive aspect of the production. "You can't go anywhere and shoot a scene for *TRON* in the real world," noted Kosinski. "Everything had to be designed and then built, either physically on a stage, or on a backlot, or digitally in the computer. It was a tremendously laborious movie to make, because we got nothing for free."

Indeed, Eric Barba's view was that *TRON: Legacy* was essentially a computer generated feature, along the lines of a Pixar production, but without a Pixar production schedule. "We had to computer generate so much of this film," said Barba, "and yet we didn't have the typical CG feature timeline of three years. We didn't have close to that amount of time. So a lot of the challenge of the movie was just figuring out how to get it done efficiently and fast."

Given the original film's cult status, however, efficiency could not in any way compromise the artful design and execution of *Tron World*. *TRON* had been conceptualized by Moebius and Syd Mead, two of the most venerated concept designers of all time; and so, in redesigning *TRON*'s environments and vehicles, the filmmakers were treading on sacred ground.



Foreshadowing the potential of computer graphics as a visual effects tool, TRON – created in 1982 by writer/director Steven Lisberger and a team of technical pioneers – employed embryonic computer graphics to tell the story of programmer Kevin Flynn (Jeff Bridges), who fights for survival in a series of gladiatorial computer games within a digital realm. Nearly three decades later, Walt Disney Pictures teamed with director Joseph Kosinski and visual effects supervisor Eric Barba to create a sequel, TRON: Legacy, using state-of-the-art techniques unimaginable at the time the first film was made. Set 28 years after the events of TRON, the film has Flynn's now-grown son, Sam (Garrett Hedlund), competing in contests against the computer as he searches for his long-missing father in Tron World.

“One of the reasons the original TRON has had such an incredible lifespan is because the original designs by Moebius and Syd Mead were so iconic,” Kosinski commented. “The computer graphics weren’t there, at least not compared to what we have now, but the design work was timeless. So it was important for me that we use the design work of the first film as a foundation for this one. It was like the DNA of our film. I wanted to imagine an evolution of that world, so you could trace the lineage of our work back to those orig-inal designs.

“At the same time, we had to bring something new to the table. So not only did we evolve new versions of the iconic vehicles, for example—the lightcycles and solar sailers and recognizers—we invented some new vehicles, as well. My idea was to imagine that the world of Tron had been sealed off on a server 28 years ago, disconnected from the Internet, and, like the Galápagos Islands, it continued to evolve in a closed system. That world continued to be refined for the equivalent of thousands of years inside the computer, as opposed to the 28 years in the real world; and as it evolved, the simulations became more realistic, more visceral, and more physical.”

That aesthetic philosophy applied to all of Tron World, which the art department mapped out to include a central city, and north, south, east and west quadrants that radiate out from the urban center. “Each of the quadrants has a somewhat distinct look,” explained Digital Domain previz and layout supervisor Scott Meadows. “The terrain outside the city is a little more natural-looking terrain, although everything is made up of 30-, 60- and 90-degree angles, as you would expect a computer to design things.” The western outlands are the setting for Flynn’s safe house— the area inside the digital world in which he has been hiding out for 28 years — while the eastern quadrant is the site of the computer’s exit portal. “The director described it as a place where the elements are broken down. It includes the sea of simulation and higher-species programs. Hovering over the area



Early in the film, Sam returns to his father’s derelict arcade, where he finds a secret computer laboratory. Though most of the film would be presented in stereoscopic format, Joe Kosinski shot real-world scenes flat to distinguish them from those set in the 3D Tron World. Production designer Darren Gilford and his crew built Flynn’s Arcade as a partial set at the Canadian Motion Picture Park in Vancouver, where the production was based. Ollin Studio – one of several vendors that collaborated with main effects house Digital Domain on the show – extended the set significantly, filling out the frame with CG buildings across the street and a distant city background.



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are monoliths, with tethers that connect to the ocean surface; and then far beyond that is the portal.”

Working from art department concepts, Digital Domain modelers built environments and vehicles in 3D—in rough form at first—and those assets were then turned over to the previz team. “We cobbled all of these environments and assets together so that we could previz the sequences,” explained Meadows. “And if nothing had been built, the previz team would build it using XSI, Rhino, Modo and other modelers.”

Creating animatics for key scenes with an in-house previz team was yet another way in which the filmmakers ensured efficiency. “Our idea,” said Eric Barba, “was that we would work with the art department to do previz, and then the previz could go straight into shot production as quickly as possible. So Scott Meadows worked with the art department up front for a long time to help Joe flesh out his movie. We built a previz system and a team to create this whole world, complete with the correct stereo cameras so we could see it on the big screen, do the layout, and make stereo adjustments right off the bat. We were able to plan everything up front, get approvals, and then go straight into production. As a result, there was a much tighter correlation between the previz and the final shots than you would normally have if you got the previz from an outside company.” The previz team grew to fifteen artists at one point, with David Rosenbaum and Patrick Perez leading the way on some major action sequences.

While Meadows and his previz team blocked out sequences, Barba and visual effects producer Lisa Beroud were conferring with Joe Kosinski and key department heads to determine how the film would be shot, how much would have to be built as practical sets, and what could be left to computer generated effects. “Basically,” stated Barba, “we developed the methodology of how we were going to shoot this film. We did that for about three months.”

Digital Domain also began researching and developing a plan for executing its 162 digital Clu head shots, which would amount to more than 13 minutes of screen time. “The Clu character really upped the difficulty level,” said Barba. “Clu had to be a photoreal version of Jeff Bridges in his prime, and he would be interacting and emoting against other characters in the film, including the older Flynn character, also played by Jeff Bridges. So we rolled off Benjamin Button and straight into this movie, with pretty much the same team intact. And instead of relaxing, it was like: ‘Okay, guess what we’re going to do? We’re going to do something even harder now’—and off we went, taking everything we had learned on Benjamin Button even further.”

Several factors made the Clu assignment even more difficult than the Benjamin Button one. “Not only has everyone seen a young Jeff Bridges,” said Digital Domain animation supervisor Steve Preeg, “but everyone has a different recollection of what he looked like. Some remember him best from *Starman*, others remember him in *Against All Odds*, others remember him in *TRON*—and he looks different in each movie! He’s a total chameleon. We had 50 different pictures of him, and, in many cases, he looks like a completely different person from one picture to another.”

After much deliberation, the filmmakers decided that Clu would most resemble Bridges as he appeared in *Against All Odds*. “The ladies tell me that is their preferred Jeff Bridges,” Eric Barba quipped, “so that was the goal. We decided to give him the kind of sexy look he had in that movie, with the same five o’clock shadow. To start the process, we got Jeff into a Mova contour rig to get his expressions and facial shapes very early on, and then we started playing with those. Rick Baker and Kazuhiro Tsuji, at Cinovation Studios, sculpted a maquette of a younger Jeff Bridges; and then Dan Platt, who is an amazing anatomical modeler, sculpted the final Clu head. He continued to refine it for a long time; and before it was done, he had worked on that character for two-plus years.”

Another issue that complicated the Clu shots was that rather than capture Bridges’ performance in a controlled setting after the shoot, the actor sitting in a chair surrounded by motion capture and witness cameras—which is how Brad Pitt’s performance as Benjamin Button had been captured—Digital Domain would have to capture the actor’s performance live, on the set. “One thing I said to Eric early on was, ‘I don’t want Jeff doing these scenes two months after we wrap shooting, trying to remember what the scene was about,’” recalled Joe Kosinski. “I really wanted to capture his performance while he was in the scene with the other actors. I’m sure he would have done a great job re-creating that performance later, but nothing replaces actors playing off each other in the moment. So I really pushed Eric to develop a system where we would capture the performance on the set, through a head camera.”

Barba and his team met the challenge, working with Gary Roberts, who helped set up the system used by ImageMovers Digital, and former *Avatar* virtual production supervisor Glenn Derry to create a helmet rig to which was attached an array of four small infrared cameras. Jeff Bridges would wear the helmet rig on the set, and the cameras would capture his facial performance from four angles. Each Clu scene would also be shot with a younger body actor, John Reardon, standing in for Bridges, and the digital Clu head would be tracked to that performer’s body.

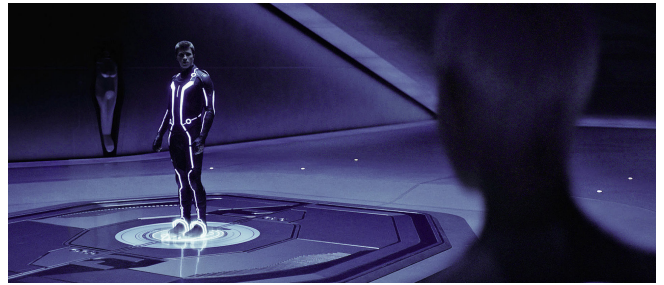
Going in, Kosinski and Barba understood that the entire on-set performance capture setup would be complicated by the fact that all of the live-action scenes set in *Tron World* would be shot with the stereoscopic rig. On Benjamin Button, Barba had synchronized two witness cameras to the primary ‘A’ and ‘B’ cameras during main unit shooting, recording the performances of the stand-in actors on set, which resulted in perfectly synchronized data between all the various cameras. “I pitched that same idea to Joe for *TRON*,” said Barba, “but there was the added complexity of stereo, which meant that each ‘A’ camera was really two cameras, and each ‘B’ camera was really two cameras—so we were going to be synchronizing with four cameras, rather than two. Add that to our two witness



Arriving in Tron World, Sam is picked up by a recognizer, the iconic police vehicle introduced in TRON. The new recognizer design reflected Kosinski’s idea that Tron World had continued to evolve as a closed system since the events of the first film, producing ever more refined vehicles and environments that still retained core elements of the originals. To facilitate efficient interaction between the designers and those charged with realizing their designs, the production art department moved into Digital Domain early in preproduction. Digital Domain modelers worked directly from 3D designs created in ZBrush to build Tron World environments and vehicles for purposes of previz.

cameras, and we would have six cameras going at any given time —plus the four head cameras on the helmet rig to get the head video. That brought us up to 10 cameras! It was crazy. Just the number of cables that would have to be run across the set to power and capture all the data to the disk recorders was going to make the whole thing more difficult.”

The stereo would also put more demands on the tracking system. In tracking the Benjamin Button heads to body actors, Digital Domain artists had relied heavily on traditional 2D paint work, rotomation and morphing to disguise minute tracking errors. But such 2D techniques would not be available to the *TRON: Legacy* crew. “Working in stereo,” commented Barba, “those types of 2D techniques immediately give themselves away. There were incredible challenges in putting the Clu head on another body and making sure it sat correctly in 3D space. If it was off by half a pixel, you could see it. We’d come up with what we considered to be an incredibly precise system for Benjamin Button; but we had to come up with an even more precise system for *TRON*.”



Ollin Studio contributed to shots of Sam being fitted into a light suit by four female programs in the Tron World armory. Ollin artists started with shots of Hedlund and the four program actresses – shot bluescreen – and then created the digital suit-up using Houdini scripts, rendering shots for both right and left eye and at high resolution to accommodate the stereoscopic and IMAX formats. Ollin also built full-CG backgrounds for the armory setting, working from art department architectural blueprints and the rough geometry in Digital Domain’s previz. Ollin developed global illumination and special shaders to match the subtle lighting in the plate.

Development and previz continued at Digital Domain as first unit began shooting in spring 2009 at the Canadian Motion Picture Park in Vancouver. Even though *TRON: Legacy* would be, in many respects, a computer generated film, with actors most often filmed against bluescreen and then inserted into CG environments, Kosinski wanted the actors to perform within real-world environments as much as possible; and so production built a number of full and partial sets on several stages there. “I wanted to make sure we built every single thing that could be built,” said Kosinski, “and limit the virtual sets to an absolute minimum—which I don’t think you’d expect in a movie like this.” The biggest and most complete set was that for the safe house where Kevin Flynn has been hiding out for nearly 30 years. “That was my favorite set. I sketched that on a napkin for the visual effects test, which is the first thing we did. So it was built completely digitally in that piece; but then we got to build it for real for the movie. To walk onto a massive set that had started as a napkin sketch the year before was a great experience for me. It was great for the actors, too, to be able to inhabit a set rather than just be on bluescreen.” Production also built large sets for the scene in which Sam first emerges into Tron World from Flynn’s Arcade and is captured by recognizers, as well as for the End of Line Club featured in the film’s third act.

Whether acting on the bluescreen stage or on a full practical set, actors portraying hero characters were illuminated foam suits created by Quantum Creation FX. Building the suits was a major endeavor, requiring the efforts of 150 artists and technicians spread out over three buildings. “Traditionally, these type of foam suits are sculpted,” noted Quantum owner and president Christian Beckman, “but we tried a little different process on three out of our ten characters. Since the character costumes were all designed in 3D programs such as ZBrush, and we had access to the actors’ body scan data, we were able to start the process by digitally fitting the 3D costume data to the actor’s body form, enlisting the help of Eddie Yang and his 3D design company. During this process we also created our internal ‘suit core’ elements with their own keying system that would later be crucial to the molding process. Once this data was finalized and approved, we sent it out to have the elements milled out of rigid foam.”

Although other companies have generated milled costume pieces from 3D digital files, *TRON: Legacy* may represent the first time the technique has been used on such skin-tight, low-profile suits. “We found that utilizing the 3D output process for this particular application still has a way to go,” Beckman said, “but it has tremendous potential, and we will continue to work with the technology in the future. Both milling and 3D printing machines are getting more and more sophisticated with detail, but I still admire and appreciate the art of sculpting by hand.”

Hand work of highly skilled artisans was still necessary when Quantum received the milled pieces, both for purposes of detailing and to fix small discrepancies between the original design and the foam suit. As a last step, Quantum artists sanded the suit’s hard positives to a polished, smooth surface prior to the final mold process. “We body-shopped them like you would a car to make them perfectly smooth on the outside,” said Beckman. “Michael Wowczuk was the department head of the



Quantum Creation FX created light suits worn by hero characters. For three of the characters, rather than sculpting the suit in clay over a lifecast – the traditional approach for building foam suits – artists started with 3D models of the costume designs, which they fit onto digital actors’ forms derived from full body scans. Quantum Creation then had digital costume pieces milled out of rigid foam, from which the crew created molds. Sculptor and mold-maker Kelly Golden preps the torso mold for Sam’s suit.



paint and body shop, where each costume was polished to an auto-body finish.”

Quantum Creation fabricators Maria Sundeen and Robin Dufay assemble a light suit for Rinzler, one of Sam’s principal adversaries.

The remaining suits were handled in the more traditional manner, with 3D scans of actors being used to create body-forms on which the suits were sculpted in clay. Quantum’s foam department then ran foam pieces in molds taken from the sculptures. “Bill Fesh ran the foam department,” said Beckman, “and he and his team ran hundreds of foam suit elements, day and night, to meet the tight schedule demands. Due to the smooth, tight nature of these costumes, it was imperative to have an outstanding foam department ensuring that the foam runs came out right.” Lead fabricators Tamara Carlson-Woodard, Marilee Canaga and Maria Sundeen and the entire Quantum crew built a total of 96 foam-constructed suits for the show.



Prior to filming, a member of the on-set crew polishes one of the helmets built by Ironhead for the suited Tron World characters. To incorporate illuminated patterns into the suits, Quantum Creation cast wire harnesses into each, which served as conduits of electrical power from battery packs – usually housed in the disk area in the back of the suit – to custom lamps integrated into the costumes.

Quantum’s Mecki Heussen and Timothy Ralston developed lighting wire harnesses that were cast into each suit and served as conduits of electrical power from battery packs to custom lamps integrated into the costumes to create illuminated patterns. “All the hero costumes and stunt double costumes had lights running through them,” explained Beckman. “We did a lot of R&D, led by Leon Laderach, to determine how we would light these suits and get the light patterns to work with the costume designs. We found a company, Oryon Technologies, that makes a screen-printed lamp—almost like silk-screening a shirt. You can create a design in a vector file, give them dimensions, and they can scale it up and literally do a screen print, with multiple layers making up the lighting. Daniel Miller was key in developing a system for measuring and patterning off of the suit sculptures, and then taking the physical patterns and digitizing them through Photoshop and Illustrator. He then could send those patterns in vector files to Oryon where the custom lamps were made.”



The form-fitting foam costumes elevated actors’ body temperatures. Between shots, Garrett Hedlund seeks relief in a portable air conditioning duct.

The lights delivered back to Quantum were extremely thin and flat, printed on screens that measured approximately 24 inches long and 16 inches wide. Quantum artists and technicians then cut out the light pieces in the sizes and shapes they needed, ran conductive thread to all of the

connecting points behind each lamp, and sealed the lamp into the suit with velcro to facilitate quick lamp replacements on the set.

The lamps were powered by nano-lithium batteries and custom inverters that were most often housed in the disk area at the back of each suit. “The suits were skin-tight and low profile,” stated Beckman, “so just incorporating these battery packs and inverters was one of the big struggles on this project. It was very tough. Where we put them depended on the character and how much light was on that character. On the main characters’ suits, which had a lot of lights, we would need up to seven batteries, and we either housed them in a pack that we aesthetically designed into the suit, or we put them in the disks. Then we’d put the inverters in the hub area of the suit, which is where the disk attaches.”

The film begins in the real world, with Flynn’s son, Sam (Garrett Hedlund) going to the dilapidated Flynn’s Arcade to investigate a message from his long-lost father. In doing so, Sam is drawn into the world of the computer. To distinguish them from the stereoscopic Tron World, these early scenes were shot 2D on a practical set that was extended by Ollin Studio. “Flynn’s Arcade was created as a set,” said Ollin visual effects supervisor Charlie Iturriaga, “but about 70 percent of what you see in the establishing shot, which is the whole other side of the street, we created in CG. This was supposed to be the real world, so the entire CG street and buildings had to be very detailed.”

Ollin Studio was also responsible for shots of Sam being suited up by four comely female programs upon entering Tron World. Ollin artists started with bluescreen footage of Hedlund and the actresses, and then created the digital suit-up using Houdini scripts. “The suit building up had to be very precise,” said Iturriaga, “and rendered for both the left eye and the right eye because this was going to be 3D. It was also going to be in IMAX, so we had to work at that resolution for this full-frame image.”

Ollin also built the scene’s surrounding armory environment. “We got architectural blueprints and Digital Domain’s previz and built the environment from those,” said Iturriaga. “So we had some rough geometry that we used as a mock-up. We did a 3D track on that and did a series of tests for the environment, doing intensive creative and technical development with Eric Barba until we got the proper look.”

Sam’s suit, like all the others, features patterns of glowing luminescence. Though Quantum Creation had built practical illumination into the suits, Digital Domain enhanced the lighting on almost all the shots in postproduction. “Some people were hoping that we would be able to just go with what we got in-camera,” noted Eric Barba, “but Joe and I always knew we would have to enhance the glows to give the suits more intense lighting or the exact color we wanted. It was still a



Sam engages successive opponents in a gladiatorial disk fight, a flashier version of the lethal contest seen in TRON, in which combatants throw spinning razor-edged disks at one another. Digital Domain created the game’s shape-shifting stadium, which consisted of eight floating glass cages surrounded by viewing stands. Digital Domain’s lighting team developed artwork to define the reflective and refractive qualities of the glass courts, and then executed the look using refraction buffers and a variety of compositing tricks.

good thing to have the practical lighting in the suits, though, because it gave us interactive lighting on the actors and made it much more real than it would have been if we'd done it all as a post treatment."

Digital Domain purposely added a slight flicker to the light glows, in part to emulate the flickering look of the suits from the first film, which had been the result of slight human error in the hand-animated roto effect. "The flicker made it look more like the original TRON," said Digital Domain sequence supervisor Karl Denham. "That look had been unintentional, but they used it in their favor, and even added a sound effect to go with the flickering. It's subtle, but it's there. So we did the same thing. The flickering also made it look as if there was a pulsing energy moving through the suits."

The subtle flickering of the illuminated patterns in the suits was just one of many instances in which the filmmakers and effects artists sought to pay tribute to the original film without sacrificing the highly sophisticated look of state-of-the-art digital effects—a consistent creative challenge throughout the show. "One of the things people liked about TRON was its retro, low-end graphic style," related Steve Preeg. "But audiences today weren't going to be okay with that. They'd just think it was crappy computer graphics. On the other hand, the fans wouldn't be happy if everything looked too different. So that was one of my big fears going in —how do you maintain that feeling and look of TRON but still keep a modern-day audience happy? Already, there are people on the Internet asking, 'How come the lightbikes don't turn perfectly 90 degrees like they did in the original movie?' Audiences back then accepted very simple computer graphics, as well as very unreal-istic game action; but today's audiences just wouldn't buy something like a lightbike turning 90 degrees. We were always fighting that sort of thing, and it took a lot of iterations to find that balance for each sequence and aspect of the movie, including the look of the suits."

Shortly after his arrival in the digital realm, Sam comes face to face with the program Clu, who appears as the spitting image of his father at the time he disappeared. Digital Domain's animation department started with the positional information — tracked by EA Vancouver—derived from the four head-rig cameras Jeff Bridges had worn on set as he



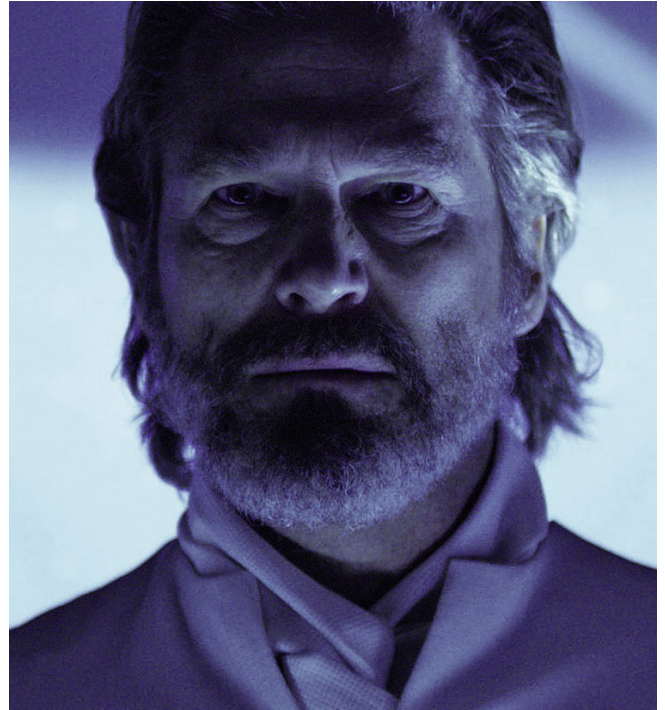
Sam and Rinzler are the last standing combatants in the disk fight. Opting to capture as much game action in-camera as possible, without having to resort to digital doubles, the filmmakers shot stunt performers executing dynamic acrobatic moves on the bluescreen stage in Vancouver. As Rinzler, martial artist Anis Cheurfa, in particular, performed incredible physical feats in full costume and helmet.



Digital Domain inserted the bluescreen performances into its expansive arena environment, and used a Massive

performed the Clu scenes, and used that information to transfer Bridges' performance to the digital Clu head, with artful tweaking by the animators. "When you age," commented Joe Kosinski, "not only does your look change, but your mannerisms change, as well. To make sure the Clu performance represented Jeff at 35 years old, the animators would sometimes tweak some of his expressions. It was a very difficult thing to do, transferring Jeff's performance to this 35-year-old digital character. In fact, I don't think there's a harder thing you could do right now in effects than what we were trying to do with this character. It would be one thing to do it as a pure display of visual effects; but this digital character was truly in support of the story we were trying to tell. I was very excited to see Clu come to life."

simulation to create 500,000 cheering spectators in the stands.



Jeff Bridges, star of the original TRON, returns to the sequel as an aged Kevin Flynn, who has been trapped within the Tron computer for nearly three decades.

Karl Denham, the sequence supervisor for all the Clu head shots, had become something of an expert in how to avoid the dreaded dead-eyed look in digital characters, having been responsible for the look of Benjamin Button's eyes in the Fincher film. Denham brought that expertise to closeup hero shots of Clu's face. "We'd found on Benjamin Button that the eyes on the live-action stand-in weren't always lit as we would have liked," Denham said. "A lot of times, the stand-in actor had no reflections or highlights in his eyes at all, so we had no reference. Since they were replacing the head anyway, they just hadn't worried too much about carefully lighting the eyes. You can get away with that if you're shooting a real human being because it's obvious, from a thousand other clues, that it's a real human being. But if you're doing a digital human, you have to have something in the eyes. If you don't, that can be the small detail that kills the whole thing. So, just as we had on Benjamin Button, we had to do a lot of digital reflections in the eyes for Clu. It was similar to what you would do on set, just putting an eye light somewhere that would give the character a little twinkle in the eye. We did the digital equivalent of that; and it was tricky, because if we did it wrong, it would look as if the character had laser-beam eyes."



*Flynn's nemesis is Clu, a sophisticated program modeled after the 28-years-younger Flynn. Creating a digital Clu head that replicated Jeff Bridges at the age of 35 represented the film's biggest visual effects challenge, tackled by the same Digital Domain team that had delivered Academy Awardwinning effects of a digitally aged Brad Pitt for *The Curious Case of Benjamin Button*.*

Another 'youthenized' digital character that appears throughout a flashback sequence is Tron, also known as Alan Bradley—Bruce Boxleitner's character in the original film. Since the character was only to appear in a couple of shots and speak only one line, Eric Barba and his crew took a more streamlined approach to the character than they had Clu—an approach that was tested when Tron's role was expanded. "We built Tron completely in the CG realm," Barba explained, "based off synchronized four-camera still photography that we did with Bruce Boxleitner." Barba sent those photographs to visual effects supervisor Edson Williams at Lola Visual Effects, a company well-known for its youthenizing effects. "We asked Edson's team to give us a likeness that would illustrate Bruce at a younger age. They gave us four still frames back, and our modeler, Dan Platt, sculpted those into our Tron character. The body actor for Tron was an amazing martial artist, and we put this 28-years-younger Bruce Boxleitner digital head on that stunt performer's body."

The flashback sequence served to fill in the narrative of what had happened within the computer system since the events of the first film—mainly, the building of Tron City, the development of advanced 'Iso' programs, and Clu's destruction of the Iso towers that leads to the sealing of the portal, denying Kevin Flynn his only escape back to the real world. Whiskytree delivered 27 environmental shots that helped to illustrate the flashback story points. "It is a sequence that

harkens back to the first TRON movie,” said Whiskytree visual effects supervisor Jonathan Harb, “and so it is designed in a very old-school way. A lot of the compositions in the sequence are what you might have seen in the 1980s—very typical matte painting compositions—and that’s the look the filmmakers strove for in our environments and extended sets. One of the environments is a portion of Tron City under construction; and then we have a few shots in the outlands, which is a crystalline place past the outskirts of Tron City. We also have a few shots back on what’s called the grid—the glass, flat area directly adjacent to Tron City.”

The end of the flashback sequence has the Iso towers being destroyed. “It’s a killer shot,” said Harb. “We built the tower in CG and then just demolished it. There are great explosion effects and cool smoke, and all these little tanks and recognizers taking shots at the Iso towers. It was all 3D work. There were a lot of animated bits; and then, for the destruction of the towers, there was a good bit of simulation. We did a lot of work inside Softimage, using ICE. We also used FUME for smoke, and some good old-fashioned photography of polyfill to give us some good photographic pieces we could use for interior lighting of the demolition clouds.”

Whiskytree created Iso digital doubles for a shot of two foreground, live-action characters leading a long line of the beings from the distance.

To distinguish it from the current-day sequences, all of the flashback scenes were created in two dimensions. “All of this was single-eye work for Whiskytree,” remarked Harb. “Unlike the rest of the movie, we didn’t have any stereo shots in this sequence. They really embraced the idea of going back in time, so they wanted it to look much more simple.”

Digital Domain added the Tron character and Clu into the sequences, and then another company, Prologue, did an overall treatment that put the scenes into a kind of screen space with stereo pieces in front. “It created the effect of looking into a window,” commented Eric Barba, “but it is a flat window.”

Back in the present, Sam—like his father before him—engages in a series of gladiatorial games within the world of the computer. The first is the disk game, a flashier version of the lethal contest in the original TRON, in which combatants hurl spinning razor-edged disks at one another. The filmmakers opted to capture as much of the game in-camera as possible. “The disk game actually has quite a bit of practical fighting,” said Steve Preeg, “but they shot it with performers who were such amazing acrobats, people will think some of the stunts are digital.” Martial artist Anis Cheurfa—cast as Clu’s henchman, Rinzler—performed some of the most incredible feats, made all the more



Jeff Bridges drove Clu’s performance via ‘e-motion capture’ technology. Rather than capture Bridges’ performance in a controlled setting after the shoot – as had been done with Brad Pitt on Benjamin Button – Digital Domain devised a production-friendly system to record the actor’s performance live, on the set. The system included a helmet rig with an array of four small infrared cameras, which captured Bridges’ facial performance from four slightly different angles. Each Clu scene was shot once with Bridges, for facial capture purposes, and then again with body double John Reardon, to whom the digital Clu head would be tracked.

astounding by the fact that he had to do them in full costume and helmet. “He couldn’t see much, and he was still doing all these crazy flips and jumps. All the background characters were digital, but 70 to 80 percent of the disk game was live-action.”

The live-action performers wore helmets that had been designed by the art department and then executed by Ironhead; but in most shots, Digital Domain tracked digital glass faceplates to the game participants. “The real helmets were amazingly built and designed,” said Eric Barba. “They were really beautiful works of art—far beyond a traditional movie prop. But sometimes there were problems with reflections. We had to be able to tie particular performers to particular environments through the lighting and reflections—but how could we do that with the real helmets on the bluescreen stage when we hadn’t established exactly what the environment was going to be at that point? The only way I could see to make it work was to track the front plates of the helmets in stereo, and then render them out in the actual environment so that the reflections would be correct. In some cases, we shot actors without helmets and added the entire helmet digitally.”

Reflections became a key issue for the entire disk game environment, which was a big coliseum with a number of floating glass cages, one disk game team per cage. “We had to figure out how all these glass courts would refract and reflect on one another,” Karl Denham recalled, “because we would be seeing through multiple courts at one time, seeing other battles going on with CG characters in the distance. We knew it could get very complex.”

Lighting lead Juan Gomez first developed artwork to define the reflective and refractive qualities of the glass courts, and then he and his team executed the look using refraction buffers and a variety of compositing tricks. “We didn’t want to render every single court with refraction and reflection and everything else,” noted Denham, “because that would have been way too complex. Instead, we rendered a buffer that gave us a refraction pass and allowed us to simulate the refraction in a composite.”

The coliseum featured a crowd of 500,000 cheering, jumping and yelling spectator programs in the background, realized through a Massive simulation. “There were 70 or 80 agents,” stated Denham, “with different levels of activity, sizes, shapes, clothes and so forth, just so we’d see some variation in the background. We needed a lot of activity to fill that coliseum background with energy and life.”



Shortly after his arrival in Tron World, Sam comes face to face with Clu, who is the spitting image of his father as Sam last saw him. For each Clu shot, Digital Domain artists began with the production plate, with John Reardon in frame, and the data captured from the Jeff Bridges helmet rig. After tracking the plate, the team replaced Reardon's head with the digital Clu head, which had been modeled to match Jeff Bridges as he appeared in 1984's *Against All Odds*. A maquette sculpted by Rick Baker and Kazuhiro Tsuji, at Cinovation Studios, served as reference from which anatomical modeler Dan Platt sculpted the final digital head. Digital Domain animators transferred Bridges' on-set performance to the Clu head, executing hand-animated tweaks to correct disparities caused by the 30-year difference in age between the actor and his character. Digital Domain created 162 digital Clu head shots, which amounted to more than 13 minutes of screen time.

When a disk game combatant is struck by the lethal object, he ‘derezzes,’ an effect seen throughout the film. The original *TRON* had suggested the derezz with a few frames of animated pulsing glow, which then vanished. The new derezz shots would be much more complex and visually interesting. “Derezzed characters and objects turn into tiny little cubes,” commented sequence supervisor Nikos Kalaitzidis, “and then the cubes diminish and disappear. They are essentially put into the trash and deleted forever. We had to figure out how that would look, and there were big questions at first.”

To enable Digital Domain to conduct derezz tests, production provided the effects team with a plate of a stunt person swinging a sword and striking a second performer. Digital Domain ingested the plate, rotated the impacted character and tracked the sword. “From there,” recalled Kalaitzidis, “we started experimenting with different looks for the derezz of the guy who got hit, using a hard-body simulation in Houdini. Coincidentally, I had tested that simulation years ago, for a Gatorade spot called ‘Shattered.’ And when Joe was talking about what he wanted for the derezz effect, he had said, ‘Make it look like that Gatorade commercial.’ That was perfect for me; and so we used that same simulation for this derezz.”

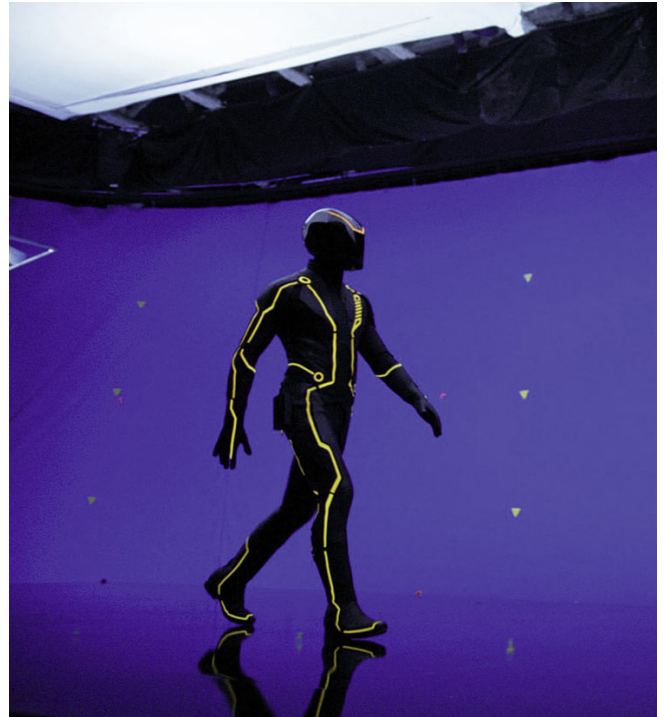
With the impact of the disk, there is an initial flash of light followed by millions of cubes spilling out and the character collapsing inward. “As he is collapsing,” said Kalaitzidis, “the cubes spread out to his limbs and fingers, and his head detaches; and when the head hits the ground, it crashes into a million cubes.” Each individual cube was a fully volumetric, 3D object reflecting the surrounding environment. “We used an ice shader to get a look that was both reflective and refractive, and we added a hot core to suggest some sort of energy inside the cube. That hot core burns brighter as a cube first comes off the body; but it diminishes and fades as it moves further away. With color and lighting and shaders, it was a fantastic effect in the end.”

Derezzing, crashing vehicles are seen throughout the lightcycle sequence, another gladiatorial game and one of the standout sequences in the original *TRON*. In the new film, 10 riders eventually dwindle to only Sam and Clu—all the rest of the bikes and riders derezz in the course of the contest, usually after crashing into light walls streaming from the rear of the lightbikes. “This was a double-whammy,” recalled Kalaitzidis, “because we had people and vehicles to derezz. The bike would crash like any other vehicle; but then parts would start crumpling and derezzing from the inside out. So the fender, for example, would crumple and then begin turning into cubes.”

The lightcycle derezzes featured the additional element of burning fuel, the substance that forms the light walls. “As the lightcycle derezzed,” said Kalaitzidis, “we introduced a liquid, which was more organic and behaved differently—and that is what made the lightcycle derezzes look so beautiful. There were all of these hot colors that looked like liquid glass, and that combined with the cubes looked really great. Houdini gave us that, and we used some internal fluid sims that we had, as well. So it was a combination of Houdini and Nuke compositing.”

Unlike the disk game, most of which was shot live-action, virtually all of the lightcycle sequence was digital; however, Joe Kosinski still wanted the sequence to have a more physical quality than did the lightbike sequence in the first *TRON*, supporting the idea that the computer had become much more sophisticated in emulating the real world.

Working with Kosinski and Eric Barba, Scott Meadows and his team devised lightcycle action and choreography in previz, using motorcycle dynamics for reference. “I ride a motorcycle, and so do a couple of other guys on the team,” Meadows commented, “so we were constantly referencing our own experience. It was different, of course, because these bikes, in reality, would probably weigh a thousand pounds and they wouldn’t turn the way a real motorcycle would. They also didn’t have suspension, so the physics were different in the way the bike reacted to impacts and jumps. All of that had to be more stylized, but most of the nuances of how you would move your body and handle the bike were similar to the real world.”



Clu strides through a packed lightcycle stadium against a backdrop of fireworks. Yannix – to which Digital Domain subcontracted rotomation and tracking chores – rotomated the live-action Clu performer, shot on a bluescreen stage, as a reflection element. Unlike non-stereoscopic films, in which 2D cheats can be used for reflections, TRON: Legacy required rendered reflections to create the appropriate sense of depth. Though the Clu suit featured practical lighting, Digital Domain enhanced the glows in many shots of suited characters, adding a slight pulsing to the illuminated patterns in homage to the flickering lights in the original film, caused by minute inaccuracies in manual rotoscoping.

Barriers created by the light walls complicated the choreography, as their purpose within Tron World was to create a maze of obstacles that would trap opponents. “There were light walls, obstacles and three different levels to deal with in the lightcycle battle,” Meadows said. “On the game grid there’s a corkscrew that takes you from the top level all the way to the bottom level. There are different ramps, as well. So we had to take into account all of these obstacles and levels when we were designing action scenarios. It was much more complicated than it was in the first movie.”

Once the sequence had been developed in pre-viz, the Digital Domain crew began replacing low-resolution characters and lightbikes with high-resolution versions for final shots. For shots close enough to show rider faces, Eric Barba orchestrated a motion capture session at House of Moves, where performers straddled a stationary bike and moved their heads as if engaging in lightcycle combat. “We had an array of four RED cameras aimed at their heads,” said Barba, “and we projected those faces onto a CGI head. We also motion-captured the bodies; and that mocap ultimately drove the CGI bodies on the bikes so that their heads would sync with their bodies.”

The team also photographed the performers’ bodies with a primary camera for purposes of reflections. “In at least 100 shots, we had to rotomate the live-action person because they were on a stunt floor that was a bluescreen and we needed reflections,” related Steve Preeg. “Normally, in a 2D movie, you would just sort of flop the image; but in stereo, because you get a sense of the depth of a reflection, we had to rotomate all of those characters so that the reflections were actually rendered. That tracking and rotomation work was sent to Yannix in Thailand.”

“Everything was so reflective,” added Nikos Kalaitzidis, “at first we were wondering how we would deal with the stereo. We’d never had to do



Clu strides through a packed lightcycle stadium against a backdrop of fireworks. Yannix – to which Digital Domain subcontracted rotomation and tracking chores – rotomated the live-action Clu performer, shot on a bluescreen stage, as a reflection element. Unlike non-stereoscopic films, in which 2D cheats can be used for reflections, TRON: Legacy required rendered reflections to create the appropriate sense of depth. Though the Clu suit featured practical lighting, Digital Domain enhanced the glows in many shots of suited characters, adding a slight pulsing to the illuminated patterns in homage to the flickering lights in the original film, caused by minute inaccuracies in manual rotoscoping.



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that before. We found that it was sometimes confusing to look at the game grid field in 3D, just because it was so refractive and reflective. When we were looking at it, we didn't even know where we were. We were using ray-tracing so the light did what it did—it bounced naturally into the camera, but we had to limit that, just to make it clearer. So we set parameters for how many bounces the light would do. It was the only way to compute it.”

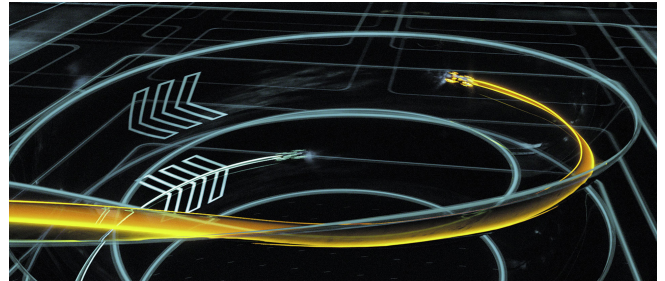
Sam survives the gladiatorial competition to join with Quorra (Olivia Wilde) and his father in an attempt to reopen the portal and escape Tron World. The third-act action starts at the End of Line Club, located at the top of Tron City's central tower. Ollin Studio provided computer generated exteriors of the club, as well as some interior set extensions. Prime Focus picked up the sequence as the characters blow the controls of a glass elevator at the top of the tower, which sends it into a freefall to a sub-level where they board a solar sailer. “The elevator and tower was a base asset we got from Digital Domain,” stated Prime Focus visual effects supervisor Chris Harvey. “We added modeling detail, shading and lighting, and then matte-painted on top of that.”

For mid and close views of the characters inside the elevator, production shot the actors in an elevator interior, against bluescreen, and Prime Focus created everything surrounding them, even reconfiguring the camera to enhance the stereoscopic format. “There's one shot, specifically, that we redid the camera on,” said Harvey, “flipping it upside down to give the audience the same sense of vertigo the characters are experiencing. We also did quite a few all-CG shots for the sequence, with digital doubles inside the falling elevator.”

Prime Focus built a sub-level environment where the characters escape the elevator to board a solar sailer. “We had to build that entire sub-level,” stated Harvey, “because all we had for it was one painted style frame. We did a lot of concept work first, and then modeled it. It's a vast underground environment, and it required that we do a lot of set building, matte painting and re-projection work.”

Prime Focus also delivered subsequent shots of the solar sailer in flight, integrating bluescreen elements of the actors with its CG aircraft. “We created the entire ship around them virtually,” explained Harvey. “Digital Domain had concept art and art department designs for the solar sailer, which looks like an updated version of the original design. We used those digital designs to rebuild the entire model, and then added details, effects and shaders to enhance the beauty of the vessel.

lighting. Digital Domain enhanced the glows in many shots of suited characters, adding a slight pulsing to the illuminated patterns in homage to the flickering lights in the original film, caused by minute inaccuracies in manual rotoscoping. In a reprise of the original film's most striking sequence, Sam takes on other combatants – including Chu – in a deadly lightcycle competition. Unlike the disk game, most of which was shot live-action, virtually all of the kinetic lightcycle sequence was digital. However, Joe Kosinski still wanted the sequence to have a physical quality to support the idea that the computer had become much more sophisticated in simulating the real world. For shots close enough to see riders' faces, Eric Barba orchestrated a motion capture session at House of Moves, where performers straddled a stationary bike and moved their heads as if interacting with other lightcycle combatants.



While limited computer graphics capability had dictated that the lightcycle race in the original TRON play out on a flat, single-plane grid – with bikes on straight-line trajectories making abrupt, right-angle turns – the new lightcycle sequence featured much more complex multi-plane choreography, with combatants using ramps and corkscrew structures to maneuver through multiple course levels. Light walls streaming from behind the speeding lightcycles caused vehicles and riders to derezz upon impact, shattering into millions of tiny cubes.

The solar sailer is quite large and intricate, and so the model had an extremely high level of detail. Also, everything was reflective, so all of our surfaces had a lot of render-time-heavy calculations.”

Prime Focus created the vast environments surrounding the solar sailer as it travels a distance of 60 miles. “The solar sailer is 10,000 feet in the air,” said Harvey, “and you see out to all these cloudscares and rock formations as they head in the direction of the portal. You see cliff drop-offs and monoliths; and then, at the end, they navigate through a large V-shaped canyon with rock formations on either side.” For the rock formations, the Prime Focus team wrote some procedural modeling and landscape tools to establish the base, and then hand-sculpted hero assets on top of that. “Because we are so high up and see so many miles of terrain, we had to have a way to quickly generate that—and then we could go in and place hand-modeled hero objects here and there.”

The canyons and rock formations had a stylized realism—real enough to look as if they were really there, but more symmetrical than what would be found in the natural world. “Everything had to be in the 30-, 60- or 90-degree angle configuration they’d established for the movie,” said Harvey. “Circuit boards are built with those angles for purposes of circuit flow; and so creating rock formations with those same angles indicated that this was a computer world.” The same symmetrical look can be seen when the characters pass through an area in which ‘Tron stars’ are just starting to fill the sky. “This is just another indication of how the computer is evolving this world. They are built in specific lines and geometric structures, as well. The idea is that the computer is trying to create a real world, but it can only do so within the parameters of a computer.”

Terragen—the landscape-generating tool first developed at Digital Domain—was instrumental in creating the solar sailer flight shots, with original Terragen developer Matt Faircloth writing custom code to optimize the program for purposes of stereo and also make it better able to create shot-specific clouds and atmospherics. Ironically, Prime Focus did not use Terragen for generating terrain—its primary function—because the landscapes it produced were far too natural-looking for Tron World.

Like all the effects vendors on the show, Prime Focus wrote an entirely new compositing pipeline around Nuke to ensure consistency in the look of its shots and to facilitate sharing of shots with Digital Domain. “There was a lot of effort in making sure that all the vendors could work together,” Harvey said. “They wanted everyone to be using the same renderer and compositing tools so we could move files back and forth relatively painlessly. Also, Joe had set a very defined style, and it was important to him that everybody’s shots were consistent with that style.”



In a flashback sequence, young Kevin Flynn, Tron (Bruce Boxleitner) and Clu overlook Tron City in its embryonic stage of construction. Whiskytree artists composited a bluescreen element of the actors with a digital matte painting of the city, one of 27 environmental shots the company delivered for the sequence, all designed to suggest the ‘old school’ look of the original movie. The flashback sequence served to fill in the 28-year gap between the first film and the second, during which the Tron computer system had simulated Tron City, developed advanced ‘Iso’ programs, and sealed the exit portal, denying Flynn his only avenue of escape back to the real world.

Toronto-based Mr. X, too, retooled its pipeline for the show, transitioning from a RenderMan-based house to one that could work in Chaos Group's V-Ray. "We had to completely change our pipeline," remarked Mr. X founder Dennis Berardi, "just to accommodate the sharing component of the show. We had ten years of history with RenderMan, and within a few months we had to build a new pipeline from the ground up. Going with V-Ray meant a complete reworking of our pipeline and a pretty major investment. It allowed us to be compatible with everyone else, but it wasn't without its growing pains."

Mr. X made contributions to 208 shots involving the rectifier, a massive edifice buried into the side of a simulated mountain and headquarters for Clu's planned military attack on the real world. Of those shots, 76 were shared with Digital Domain, which did the rendering and compositing—but Mr. X's work was significant, even on those shared shots, as the team matchmoved cameras, and executed the layout and animation. The remaining 132 shots were Mr. X's alone, and most required the incorporation of digital environments with foreground bluescreen plates or live-action shot on partial practical sets representing rectifier interiors.

A very small practical set had been built for the scene in which Flynn, Sam and Quorra dock the solar sailer at the rectifier, and then engage in combat with Rinzler. "There was a set for the docking port," stated Mr. X visual effects supervisor Aaron Weintraub, "which is where the characters disembark the solar sailer and come down stairs into this docking area. They had built one-and-a-half car lengths of practical solar sailer, a staircase and a little bit of floor to go around it." Production had also built a practical set piece for the bridge of Clu's 'throne ship,' which he docks atop the rectifier. Mr. X extended the throne ship set for shots from the bridge, adding wing extensions and digital glass into windows for purposes of reflections.

Among the shots Mr. X shared with Digital Domain were interiors featuring Clu. "In a handful of shots," said Dennis Berardi, "we see Clu in the throne room, which is an interior environment that we helped to create. He also appears on the bridge, which was another of our environments. In those shots, we'd take the original photography with the Clu stand-in, key the plate, do all the environment work, get the environment approved by Eric and Joe; and once the layout was approved, we'd light and render and comp the environment and give them back the new plate. We'd give them our camera setup, our Nuke setup, and all of our scripts so they could add the head — which of course was the most complicated part. It was a great collaboration, but it was very complicated to attempt that level of integration across companies."



At the End of Line Club, atop Tron City's central tower, Sam, Quorra (Olivia Wilde) and Kevin, attempting to escape the city, blow the controls of a glass elevator, sending it into a freefall. Prime Focus created the shots, starting with a base asset of the elevator and tower from Digital Domain, to which the team added modeling and matte-painted detail, shading and lighting. For views of the characters inside the elevator, production shot the actors on a small set, against bluescreen. Prime Focus integrated them into their shots and surrounded them with a vast CG environment, reorienting the camera to enhance the stereoscopic format and create a sense of vertigo.

Mr. X also provided exterior views of the rectifier in shots of the massive structure emerging from the mountainside and taking flight. “The rectifier is actually a huge ship measuring two miles long,” said Aaron Weintraub, “but we don’t know that it’s a ship in the beginning. It isn’t until Clu gets Flynn’s disk to energize the rectifier that we realize it can fly.”



In the subterranean bowels of the tower, the Flynns and Quorra board a solar sailer, another craft introduced in the original film. Prime Focus built the large and intricate solar sailer model from art department designs, adding modeled and painted details and developing multiple shaders to enhance the vessel’s delicate beauty. Reflective surfaces translated to time-heavy calculations in the renders. Prime Focus also delivered shots of the ship in flight, surrounding it with expansive environments and cloudscape as it travels 60 miles through Tron World, toward the portal. To generate a lot of terrain quickly, the Prime Focus team wrote procedural modeling and landscape tools to establish a base, then hand-sculpted hero assets only as needed.

Mr. X modeled the entire rectifier ship, starting with art department designs and the rough model used in Digital Domain’s previz. Unlike many of the other environments and vehicles in the show, the rectifier had not been fleshed out or detailed to the extent that it was a usable asset for final shots. “We took it from the concept art and previz stage,” explained Weintraub, “and added our own designs for detailing and did a final modeling pass on it. In terms of textures, our real-world reference was always submarines—but since this was Tron World, it wasn’t supposed to be exactly photoreal. It was a real world, but as it would be created by a computer, and so why wouldn’t everything be perfect? All the corners would be perfectly sharp and all the textures would be perfectly smooth; but at the same time, the rectifier was an environment where tanks had been driving around and armies had been walking the floors—so how much scuff do we put on the floor? Why would a tank in a virtual world scuff up a floor? The most difficult part of this project was figuring out this hybrid of perfection and realism in the look of everything.”

In addition to modeling the rectifier itself, Mr. X added texture and details to the military vehicles and ships seen within the massive ship. “The rectifier is full of lightjets and recognizers and tanks and guns, et cetera,” observed Weintraub, “which had been pre-built during the design phase. They turned those assets over to us in whatever state they were at, and then we finalized them.”

Mr. X also worked on a number of shots that required enhancement of disks used as weapons in the fights between Rinzler and Quorra, and Rinzler and Sam. “They threw around real prop disks on set,” Weintraub explained, “and then we enhanced them or replaced them with full CG disks that had spinning blades and glows. The look of sparks coming off when the disks collide had been established in the disk game sequence, and we used particle systems for those sparks. Also, as the disk flies through the air, it leaves a heat signature, kind of a jet-wash look that distorts the background.”

The fights within the rectifier lead to the third major action set piece in the film, an aerial dogfight between six speeding lightjets—craft new to the TRON iconography—as the Flynns and Quorra attempt to make their way to the reopened portal. While the three main characters, Flynn, Quorra and Sam, were practical throughout most of the lightjet sequence—the actors shot on gimbaled cockpits—all of the background pilot characters, vehicles and environments were digital.

Like the lightbikes, the lightjets are formed from batons carried by the main characters. “The idea,” said Eric Barba, “is that the vehicles are first outlined in these artfully tailored lines; and then they form more and more complex shapes in a rezzing-on effect, which is the basis for everything in Tron World.”

Whereas Digital Domain animators had been constrained by the rules of physics in animating the lightbike sequence, Joe Kosinski was open to somewhat more fantastic lightjet animation. “The lightjets are supposed to be very nimble little jets that are moving 600 miles per hour,” said Steve Preeg. “One of the big challenges of the sequence was to make it look amazing and yet not too farfetched.”

Another challenge was just selling the illusion of high speed in a mostly black environment featuring mile-high monolithic black rocks. “There was nothing on these monoliths to suggest scale,” Preeg remarked, “because they were very smooth and featureless; so it was very difficult to create a sense of scale and time and space as the lightjets flew past them. We helped the sequence a lot by adding wispy fog, which could be close to camera and create a sense of speed.”

“It was amazing how much atmospherics we needed to make the lightjets look alive,” added Nikos Kalaitzidis. “In addition to atmospherics, that sequence had a lot of CG derezzes, crashes and explosions—but no traditional fire explosions. Everything had more of an electronic look, rather than combustible. There was some smoke, just to add visual interest. We figured that maybe the smoke came from the liquid glass that the lightjet is made of.”

In the course of the dogfight, fire-damaged lightjets crash into the ‘sea of simulation,’ which was among the most surreal of the film’s digital environments. “We got artwork for the sea of simulation,” Kalaitzidis recalled, “but we were still a little unclear on the concept at first. We were like, ‘What’s a sea of simulation?’ In the end, it was a sea made out of millions of cubes.”

“It’s a large, simulated ocean,” Eric Barba elaborated, “made up of these cubes that represent the simulation. You get a sense that there is watery movement, but not a real water surface. The sea is such a vast thing; Tron World can’t really make it a solid thing. From far away it seems like it is because you are at this powers-of-ten distance from it. But just as happens with an image on a



Having arrived at the rectifier – Clu’s massive ship, buried in the side of a mountain – Sam engages Rinzler in a final disk battle. Mr. X created the ceiling of the ship and the front windshield, into which the team composited a background environment that included the Sea of Simulation, giant monoliths and the exit portal. Mr. X created and tracked a CG disk into Sam’s hand, as well as one on his back, and applied glow and heat distortion effects as the thrown disk flew through the air. The team also enhanced suit glows, using paint fixes to cover for dimming practical suit lights.

computer screen, the more you zoom in on it, the more you see the pixels—or, in this case, the cubes. Those things are there to remind us that we’re in a computer simulation.”

The characters make their way to the portal, represented as a beam of light, somewhat similar to the portal in the original film. The portal exit in TRON had been represented by a camera moving backwards through a field of very simple graphics. “We were still working on the look of that with Joe in the last few weeks of the show,” said Barba. “What we came up with was fairly elaborate; but we really don’t see the characters sucked away. Instead, there is a large, destructive event that takes out the portal and everything with it. So there is a moment where the audience doesn’t know what happened to Sam and Quorra. You know the portal is there, you know it is activated, but because of all the destruction, you don’t really know if they made it out or not, at first. You only know that when you see Sam back at Flynn’s Arcade, wearing the remnants of Tron World around his neck, suggesting a possible future film.”

Any such future film would benefit enormously from what Barba and his international team of effects artists learned in the course of creating more than 1,500 shots for TRON: Legacy. Barba took special pride in the fact that in working closely with the director and the art department on the development of the film from its earliest stages, Digital Domain, his ‘home court,’ had served as considerably more than a visual effects company. “We really serviced the creative end,” asserted Barba, “and I’m very happy about that. Rather than act as just a visual effects vendor on this film, we provided a creative partnership with Joe and helped him to see his vision through.”

Seeing that vision through was a three-and-a-half-year project for Joe Kosinski. “The only thing that sustains you through all those years,” Kosinski commented, “the only thing that gets you out of bed at 4 o’clock in the morning to go have a bad cup of coffee and be on set for 16 or 17 hours, is a creative drive and a creative fire. This project ignited that for me.”



Sam dispatches Rinzler, then rides an elevator platform to the top of the rectifier conning tower – where Clu’s throne ship is docked – fighting off a sentry who plummets through the elevator shaft to his death. Production shot the fight and fall on a hexagonal platform situated just a few feet above a safety-matted bluescreen floor. Mr. X painted out safety rigging from all the characters, and enhanced suit glows. Though Mr. X animators used the initial flipping motion of the stuntman before he hit the mat as animation reference, they ultimately replaced him with a digital double to create the full performance as he fell through the elevator shaft. Mr. X filled out the frame with a digital environment that included rectifier catwalks, a section of the throne ship, and the elevator shaft.



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Sea Quest

By Joe Fordham

During postproduction on *Prince Caspian*—the second of Walden Media’s filmed adaptations of C.S. Lewis’ Narnia chronicles —Walt Disney Pictures engaged director Michael Apte to embark on preproduction of a third film, *The Voyage of the Dawn Treader*. Working with visual effects supervisor Jim Rygiel and visual effects producer Tamara Kent, the production sought out locations and delved into methods for navigating a voyage through Narnia’s more distant realms. Cost evaluations, however, caused Disney to step aside. Twentieth Century Fox took over, continuing to work with Apte, and enlisted a new production team, including visual effects supervisor Angus Bickerton and visual effects producer Barrie Hemsley. “They had been through six or seven different bid situations,” remarked Hemsley. “Idea One was to go to Malta and Prague. Idea Two was to go to New Zealand and Mexico. Idea Three was Australia. They went around the world for two years with Michael Apte.”

The story—as defined by the screenplay by Christopher Markus, Stephen McFeely and Michael Petroni—began with now-teenage Lucy Pevensie (Georgie Henley), her brother Edmund (Skandar Keynes) and their argumentative cousin Eustace (Will Poulter) being transported from England into a Narnian sea. King Caspian (Ben Barnes) hauls them on board his ship, the *Dawn Treader*, and brings them along on a quest to find seven magical swords belonging to seven displaced Narnian lords.

The narrative restructured elements of Lewis’ novel and built toward an action climax with an evil force that threatens to destroy the kingdom; yet Apte strove to retain the spirit of the book and the earlier films’ realistic tone. “The previous films were grounded in a very earth-like Narnia,” noted Angus Bickerton. “They were populated by minotaurs, fauns and talking creatures, but they didn’t veer too far into fantasy. C.S. Lewis saw his Narnia stories as fables that contained a Christian message, but he didn’t hit you over the head with that message. He was also fascinated by medieval imagery; and, clearly, elements in *Dawn Treader* were derived from medieval concepts. But the biggest challenge was the fact that this whole quest was a voyage at sea. Everyone felt that if we shot at sea there would be no way to control the budget. History has proven this to be the case on films like *Mutiny on the Bounty*, *Jaws* and *Pirates of the Caribbean*. Fox mandated a strict budget; and that meant we had to shoot in a controllable way, although it had to be believable when the characters were at sea.”

The filmmakers set up operations at Village Roadshow Studios in Queensland, Australia, utilizing the studio’s soundstages and the area’s spectacular coastal scenery. To anchor the shoot firmly on dry land, production designer Barry Robison built the *Dawn Treader* as a full-scale gimbaled set piece, which was filmed at Cleveland Point, on a spit overlooking the ocean. Illustrations in the novel inspired the ship’s design. “Pauline Baynes illustrated all the Narnia books without any discussion with C.S. Lewis,” observed Bickerton. “She apparently had a discussion with him later in

life, after she'd completed all the drawings, and he simply said, 'They're perfect.' We referenced those drawings quite heavily. Barry Robison described the Dawn Treader as being as colorful as a big fairground swing ride. That's what he went for, and the details in the design were fantastic."

As built by the production design team, the fanciful vessel was 120 feet long, constructed as a steel frame clad in wood and fiberglass, and detailed with polyurethane foam pieces. The hull extended from two feet below the waterline to one-third of the way up the main mast, topped with an ornate poop deck aft and a colorfully painted dragon's head forecastle. Three spars extended from the top of the main mast to support rigging and the bottom third of the sail.

To simulate motions of the ship at sea, and allow repositioning in orientation to the ocean, the 76-ton structure rode on a powerful hydraulic motion base. "It was a monster," commented special effects supervisor Brian Cox. "We had a thick concrete foundation with tons of reinforcing. The gimbal acted like a big bearing in the middle. We could rock the ship in three directions, and spin it around to suit the position of the sun."

For more violent motions of the Dawn Treader in a storm, the special effects team built a second gimbal on Stage 5 at Village Roadshow Studios, and shot the new stage setup after the exterior shoot. "The production took the boat off our first gimbal, broke it into bits, trucked it back to the stage, and then rebuilt it on our rig," Cox explained. "We reused all the hardware and hydraulics for this rig, including all the Infrasonics actuators that measured the movements." To accommodate the extreme range of motion required for the interior shoot, the construction team removed portions of the vessel. "They left off the head and tail of the ship to allow for the range of movement we needed in the studio. That also reduced the weight so we could really move it around. It had fifteen degrees of motion sideways and either side of center, and six degrees end to end. We controlled that by joystick control, and then recorded the motions and played them back for multiple takes."

The special effects team also built six gimbals using industrial airbags to manipulate interior sets, including the Dawn Treader's cabins, oar deck, hold, map room and captain's quarters. "The biggest airbags were nearly three feet across," related Cox. "We imported them from Germany, and they were very adaptable, with big volumes and low pressure—about 40 p.s.i. We filled them using an industrial compressor outside the stage, piped the exhaust out to that and lagged it to keep it quiet for filming. We had a triangular base of airbags below each set, and we controlled the motion using Temposonics hydraulic actuators, so it was a pretty sophisticated rig. We could heave sets up into the air, and do any combination of motion."

To provide backgrounds for wide shots of the Dawn Treader at sea, the visual effects department conducted a second-unit shoot of oceans and scenic vistas using a refitted ice-breaking rescue tug. The live ocean plates enabled Apted to establish realistic sea views in the main body of the film before using digital sea simulations in later action scenes. "The film is heavily real at the beginning, with real plates and real water," stated Barrie Hemsley. "We slowly progressed into CG water; so by the end of the film



In The Chronicles of Narnia: The Voyage of the Dawn Treader, Lucy Pevensie (Georgie Henley), her brother Edmund (Skandar Keynes) and their cousin Eustace (Will Poulter) explore the outer realms of the fantasy land of Narnia with King Caspian (Ben Barnes), Reepicheep the

we were into fully CG simulations, with the ship being moved around in a storm and giant creatures fighting, all in one massive synthetic environment that we generated at The Moving Picture Company. We got away with that because we had sold the illusion of them being at sea earlier in the film.”

talking mouse and the mystical lion Aslan. Director Michael Apted brought to life new creatures and environments, shot mostly in Australia, aided by visual effects supervisor Angus Bickerton, the makeup team at KNB EFX Group, special effects supervisor Brian Cox, and five visual effects vendors in London.

MPC generated the majority of ocean-set scenes, and served as the main visual effects vendor on the film. One of MPC’s major characters, returning from Prince Caspian, was the valiant talking mouse, Reepicheep. Framestore also returned to build on its work from the previous Narnia film, resurrecting the majestic talking lion, Aslan, as well as providing numerous other mag-ical creatures and effects, old and new. *The Senate*, Cinesite and The Mill Film rounded out the vendors, along with an in-house visual effects unit in London. “Our in-house team consisted of a ‘ragtag fugitive fleet’ of 3D and 2D artists,” quipped Hemsley. “We made a big push early on to get a complete layout of the movie, tackling as many bluescreens and greenscreens as possible and adding ‘post-viz’ placeholders for CG creatures. Within a few weeks of the film being cut, we had a viewable temp version that helped us ascertain who was doing what, and what shots needed work. Later on, if we wanted to try out ideas, our artists bashed together shots in After Effects, Shake, Nuke and Cinema 4D. They worked on a number of creative shots and matte painting extensions.”

To ground fantasy characters in reality, the production returned to one of the franchise’s key contributors, KNB EFX Group, reuniting the Oscar-winning team of creature and makeup effects supervisors Howard Berger, Greg Nicotero and Tami Lane. Work began in early preproduction with KNB artisans in Chatsworth, California, creating a crew of Narnian Dawn Treader deckhands, as well as new characters and conceptual work. “Michael Apted wanted to do a little bit of new discovery in the world of the Narnians,” remarked Howard Berger. “But, due to budget restrictions, they also wanted to find ways to do things as practically as possible, augmenting digitally only when they really needed it. We redesigned the minotaur, for example, and figured out a way of building a full-body minotaur suit for actors to wear without using the greenscreen legs that we’d used before.”

KNB designer John Weaton created Photoshop minotaur concepts, from which Joey Orosco sculpted the full-body creature suits. The crew cast a foam latex understructure that was covered in a sewn spandex skin hand-tied with a blend of human and yak hair. Sculptor Warren Mahy and mechanical designers David Wogh, Jeff Edwards and Lon Muckey then engineered articulation of backward-bent leg extensions. “The performer’s foot was at an incline and fitted into a custom shoe,” Berger explained. “That shoe came down into a welded plate that had the hoof on it, with non-slip treads to allow for grip on slippery decks. It was difficult to wear for long periods of time, but our creature performers—Shane Rangi and Tamati Rangi—never complained. In



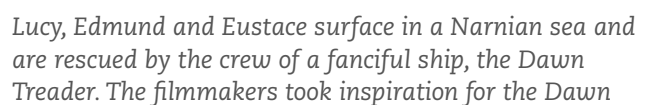
For the opening of the film, set in World War II-era England, production designer Barry Robison built a street set backed by bluescreen in a parking lot adjoining Village Roadshow Studios in Brisbane, where the production was based. The Senate shot photographic studies of King’s College, Cambridge, in England, and created a digital mockup of the location to guide placement of passersby and traffic. After the shoot, The Senate returned to Cambridge to shoot more detailed textures, and used that

[illegible]

onscreen leg extensions, including the lead
er, and a secondary faun, Morgan (Morgan
lavery along with a dwarf named
ormer Chris Cruickshanks. Paul Katte at
the Australian performer, and KNB then
Trumpkin, the dwarf in Prince Caspian.
Cruickshanks was reddish-brown, and had far
had a slave look, where he was very
ne Dawn Treader crew, Tami Lane cleaned him
pieces for him, and eyebrows, and a whole

in 1940s England, where they have been
effects team set the scene with photographic
action then referenced for filming live-action
has a theme park next to it with a gigantic car
small partial set there with a huge bluescreen,
erated shot. After the Walden Media logo, it
The camera pulled back past towers, which for
A Spitfire flies by, interrupting the illusion,
own into our car park element of Cambridge

A large, ornate ship, the Dawn Treader, is being assembled on a construction site. The ship features a large dragon head at the bow and a purple sail. A crane is lifting a section of the ship.



Fantasy intrudes into the Pevensie children's lives when they notice a painting of a sailing ship begin to animate on the wall in Lucy's bedroom. To create the image of the vessel at sea, MPC built a detailed digital model of the Dawn Treader and referenced stock footage of stormy seas from the 2003 square-rigger epic *Master and Commander* to generate CG stormy waves. Framestore employed a still frame of MPC's render of the boat in the ocean to create a hand-painted image, which they then brought to life with Corel Painter illustration software. "Corel Painter had a nice over-painting function and realistic-looking brush strokes," related Framestore visual effects supervisor Jonathan Fawkner. "We painted onto the frame, and then derived motion vectors from the moving footage and applied that to our painting."

Treader's design from a colorful carnival ride and from illustrations in C.S. Lewis' novel. To create a controllable shipboard shooting environment, safe from the vagaries of the open ocean, the art department and construction teams built the ship as a full-scale set on dry land overlooking the ocean, about 30 miles from Village Roadshow Studios. Brian Cox's team mounted the 76-ton vessel on a hydraulic gimbal to simulate its motion.

Water gushes from the painting, flooding Lucy's bedroom and sucking the Pevensies and Eustace into an underwater realm. The special effects team rigged the painting frame with five fishtail water hoses—one along each side, and a fifth positioned diagonally—which created the illusion of a solid volume of water. Framestore digitally enhanced the flow with water elements filmed during postproduction by Leigh Took's Mattes and Miniatures, at Shepperton Studios in England.

The children attempt to stem the flood by removing the picture from the wall. Brian Cox's team rigged the detached gushing picture frame with an extendable greenscreen water chute fastened to the back of the frame, with the wall removed. Framestore then used clean passes of the intact bedroom wall and textures of the reverse of the frame to rebuild the portions of the set behind the picture, creating the illusion that the plume of water was pouring out of thin air.

The children drop the picture to the floor and are engulfed as water fills the room. The production filmed flooding shots on a second bedroom set positioned on four poles above a water tank on the studio backlot. Brian Cox's team lowered the set into the tank, creating the impression that the flood level was rising. Framestore added images of Cambridge in the windows, distorted and refracted as if seen through layers of water.

The flooding bedroom scene became a showcase for the stereographic 3D presentation of the film that Fox commissioned during postproduction. Working with stereographer Ed Marsh, Framestore generated right-eye and left-eye renders of the scene and created an 'interocular pull' as the animated painting came to life—manipulating stereo perspectives to create a sense of telescoping z-depth—transforming the image from a flat plane to full



As Lucy gazes over the bow of the Dawn Treader, translucent water spirits known as naiads swim alongside the ship and play in the waves like dolphins. The Mill Film generated naiads as keyframe-animated anthropomorphic female water creatures, integrated into ocean plates shot in Australia, along with elements of either the full-scale vessel or a digital Dawn Treader generated at The Moving Picture Company. The Mill Film artists developed naiad animation simultaneously with effects of water displacements, splashes and fluid

stereo depth to emphasize the transition into Narnia.

Lucy, Edmund and Eustace emerge into an ocean from which they are pulled to safety by the crew of the Dawn Treader. The production filmed the performers in a 150-foot-square by 40-foot-deep water tank, with a bluescreen backdrop and dark gray interior walls. The harsh Brisbane sunlight, however, created caustic light patterns on the water tank walls. To remove unwanted reflections, second unit shot matching-angle ocean elements that MPC rotoscoped into water tank plates and blended with digital Dawn Treader elements.

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On board, Lucy is thrilled to be reacquainted with Caspian and his Narnian crew, in particular Reepicheep. The production filmed Reepicheep scenes using a greenscreen dummy mouse as a guide for actor eye-lines, while creature performer Steven Rooke delivered temporary dialogue. The production later rerecorded Reepicheep's speech, first with veteran performer Bill Nighy, and then with comedian Simon Pegg. "We animated quite a few scenes with Bill Nighy's voice," noted MPC visual effects supervisor Adam Valdez. "He definitely brought a wisdom to the character; but the production decided they needed a different timbre, perhaps retaining some of Eddie Izzard's high-energy voice performance from Prince Caspian, which made Simon Pegg a good alternative. The intent was to remain faithful to what we had done before, but still recognize that Reepicheep had aged. This is his last film in the series, and he makes a very dramatic self-sacrifice at the end. To make that feel like a comfortable decision required a certain maturity in his character."

Reepicheep's range of expression required a revamp of the animated character, which MPC CG supervisor Kevin Hahn and lead modeler Sam Rowan oversaw, improving resolution in Reepicheep's mouth, and subtly moving the rodent's eyes closer to the front of his face to allow for more expressive closeups. Reepicheep's fur design incorporated grooms established in Prince Caspian, which were updated in MPC's Furtility hair simulation software, with subtle aging effects and bushier eyebrows. Lead character technical director Ben Jones re-rigged keyframe controls that enabled animation supervisor Gabriele Zucchelli and his team to create global deformations in the model, emulating a more dexterous fleshy quality in the mouse's body.

MPC generated digital doubles for all members of the Dawn Treader crew, as well as hero assets for faun legs, tracked to performers at mid-thigh and detailed with fur and flesh simulations capable of withstanding close scrutiny. For shots of the minotaur Tavros delivering dialogue, MPC created digital head replacements. Minotaur characters were otherwise played as photographed with KNB's full-body creature suits, which took a beating from practical wave and water spray effects that Brian Cox's team fired across the ship during storm scenes.

For wide establishing shots of the Dawn Treader at sea, after Lucy, Edmund and Eustace come aboard, MPC composited its digital ship into photographic sea plates. Closer angles featured the practical ship enhanced with CG rigging and sails to extend the mast to its full height.

Early in the journey, Lucy gazes over the Dawn Treader bow and catches sight of a group of translucent anthropomorphic water spirits, naiads, that playfully splash through waves like dolphins. Naiads were envisaged as aquatic equivalents of dryads—elemental tree nymphs seen in earlier Narnia films. As reference for the water spirits, the production shot footage of a performer in a water tank. The Mill Film then explored naiad concepts. “We played around with mermaid concepts,” remarked The Mill Film visual effects supervisor Sara Bennett. “We added different fins and fish tails to an elegant-looking woman made of water. We came up with a lot of bizarre creature designs. The production then asked us to make the naiad a younger girl, cute and round-faced.”

The Mill Film generated the naiad model using a cocktail of 3D modeling tools—Autodesk XSI, Maya and Mudbox—while, simultaneously, animation supervisors Jean-Claude Deguara and Neil Roche experimented with animation in Maya. “It was hard to nail the naiad concept on a still frame,” said The Mill Film CG supervisor Nicolas Hernandez. “What we saw of her performance depended on the motions of the water. We spent quite a lot of time experimenting with growing shapes and revealing the creature’s face with water emissions, warping and refractions.”

The Mill Film modeled and rigged the naiad through its creature pipeline, then cached the model with fluid dynamic simulations that broke down into multiple renders and effects passes, which compositors blended with ocean plates and 2D photographic splashes. Fluid dynamic simulations were developed primarily in NextLimit’s Realflow. “We used Audition software for the effects animation,” said Hernandez, “created the main sea simulation with NextLimit’s Realwave tool, and generated all the spray with Realflow. Then we added splashes and extra simulation in XSI, and did texturing in The Foundry’s Mari. For secondary effects, we used *Side Effects Houdini* and XSI.” For an appearance of the naiads later in the film, The Mill Film generated views of the creatures swimming toward their underwater home, with 3D geometry suggesting mysterious rock formations.



The proud warrior mouse Reepicheep, who distinguished himself in battle in the previous film, Prince Caspian, develops an antagonistic relationship with the argumentative Eustace and then gradually becomes a mentor to the youth. The production filmed Reepicheep scenes using a greenscreen mouse shape on set, while a performer delivered a temporary voice track off-camera. To handle the range of emotions required for Reepicheep, MPC artists revamped the model of the character they had created for Prince Caspian, developing more expressive details in the face and incorporating a slightly more grizzled fur groom to suggest maturity and wisdom.

The Dawn Treader arrives at its first port of call, Lone Island, which consisted of Australian plate photography enhanced with digital matte paintings and environment work supplied by Cinesite and the production's in-house visual effects team. The crew disembarks at the quayside, constructed as a partial set in Brisbane, which Cinesite matte painter Sevandalino Khay enhanced with CG set extensions.

Caspian and his crew discover Lone Island's main town of Narrowhaven strangely deserted. Barry Robison designed the environment as a town square, which he built on the Village Roadshow backlot. Cinesite enhanced the set with digital top-ups and terrain extensions. *The Senate* also provided digital backdrops for a scene set in a Narrowhaven bell tower, filmed on a partial soundstage set. High-definition production plates of the monochromatic structures presented a challenge in establishing realistic scale. "We had to completely re-invent our approach to compositing," said Cinesite 2D supervisor Matt Kasmir. "The depth of field was so massive, there was hardly any aerial fogging or loss of focus further away from camera. That made it difficult to break out 3D layers, particularly in shots where there was very little parallax."

The Dawn Treader crew discovers Narrowhaven citizenry enslaved to an evil green mist that threatens to engulf the city unless it is appeased by human sacrifice. For wide shots of the mist out to sea, the production shot ocean plates of a sailing vessel which Cinesite CG supervisor Stephane Paris blended with matte-painted layers of greenish fog that engulfed the ship.

The mist was a narrative device conceived to unify the novel's allegorical themes. "In the original Dawn Treader book," explained Angus Bickerton, "the quest was to find the seven lost lords of Narnia, and along the way the characters ran into all sorts of temptations. In our film, we bound that together with a center of evil, represented by green mist. Every time characters were tempted, the mist appeared as a signifier that temptation was coming. It was a way of answering the filmmaking conundrum of C.S. Lewis' theory that logic was



As it had for previous Narnia films, KNB supplied makeup effects and practical creature effects to ground the fantasy in tangible reality. A contingent of Australian artists joined makeup effects supervisor Howard Berger and a small group of California makeup artists to handle on-set applications. Prosthetics supervisor Tami Lane applies final details to actor Chris Cruickshanks.



Two minotaurs (Shane Rangi and Tamati Rangi) – created at KNB as full-body creature suits, with backwardbent leg extensions and mechanical heads featuring radio controlled lip-sync – serve as Dawn Treader deck hands.

unimportant as long as the reader understood the fable. But Hollywood stories always demand logic—the audience always wants to know why events happen—and so we had to keep those ideas in constant balance. It sometimes felt like we were making the world’s first \$150 million theological blockbuster.”

After Lone Island, the Dawn Treader travels to Coriakin’s Island, where characters encounter what appear to be invisible giants that leave oversize footprints on the beach. Brian Cox’s team rigged invisibility gags using wirework to manipulate performers and props on set, and flew hollow spears down monofilament lines into the sand. Framestore augmented practical effects with digital paint-out and animated flying weaponry. The production generated invisible giants’ footprints by painting blue latex paint onto the leg of an effects technician, who jumped around in a sand pit on one leg. Framestore extracted the blue foot, tracked footprints to the beach, and then digitally reconstructed areas the foot concealed.

Further inland, Lucy encounters an invisible mansion that manifests when a magic spell is lifted, as does its eccentric occupant, Coriakin (Billie Brown), who appears through a shimmering optical distortion when Lucy wanders into his library. Invisibility effects were inspired by nature reference. “I found some amazing footage online of a talk by oceanographer Dr. David Gallo, showing how an octopus camouflages itself,” related Angus Bickerton. “The animal mimics its environment by not only changing its skin color, but also by changing its shape. If it rests on a bed of coral, it imitates the coral texture by puckering its skin, and it disappears into the background. We used that as an idea for how Coriakin camouflages himself.”

The Senate created Coriakin’s invisibility reveal, and set the template for all invisibility effects in the film. “We wanted to emulate the way the octopus appeared to step out of its background,” said Richard Higham. “We remodeled and rigged a cyberscan of Coriakin and motion-tracked that to the actor. We then projected cleaned-up background textures onto that geometry, which at the beginning of the shot aligned perfectly with the plate, so Coriakin appeared invisible. As the camera moved forward, the perspective shifted, revealing him. On top of that, we added refraction shaders that created distorting effects on the background. Then we added an inky bleed, like drops of ink on paper, which



The Dawn Treader arrives at Lone Island, an island with a central fortress settlement, known as Narrowhaven, which first appears strangely deserted. The production aimed to capture as many natural scenic vistas and sea plates as possible to provide a real-world foundation for creating fantasy environments. Toward that end, the filmmakers used a refitted ice-breaking rescue tug, which closely resembled the hull dimensions of Caspian’s ship, to conduct an extensive secondunit shoot, during which they gathered high-definition ocean plates and photographic scenic material that visual effects artists employed to create matte painting enhancements. The production filmed Narrowhaven exteriors in Australia, using a façade backed by bluescreens. Cinesite enhanced Narrowhaven scenes with digital set extensions of structures built as 3D geometry patterned after an ancient Mediterranean military settlement in Malta, then layered in scenic elements of mountains and distant sky, creating illusions of scale and parallax.



made the invisibility effect appear to melt away as it lost its effect, revealing Coriakin.”

Framestore adapted the effect to reveal the exterior of the mansion, generated from scenic textures of Waddensdone Manor in Buckinghamshire, England.

“We built a 3D model of the building, and then lit and painted details onto that,” said Jonathan Fawcner. “We stuck a big dome on the roof and added ivy growing up the outside.” Unlike the Coriakin reveal, the mansion appeared from a fixed perspective, so Framestore devised a method of camouflaging the building’s geometry by manipulating background textures. “We projected the background onto our matte-painted mansion. We baked the textures into a point cloud, jumbled up that point cloud in 3D, and then blended from one point cloud to another. It was tricky, but it generated the reveal as a geometry-based transformation, rather than a simple fade-up or a glassy refraction.”

Before Coriakin appears, Lucy discovers a book of magic spells on a lectern in the library and investigates its contents. *The Senate* created an effect of embossed letters moving across the cover of the book, forming its title, and animated a sculpted cherub ornament to move on the lectern. For low angles looking up at Lucy, *The Senate* extended the set with a tall domed ceiling, and generated a particle simulation that blended with a practical effect of falling paper snow that magically floats down around Lucy.

Reading from the book, Lucy discovers an illustration of a beautiful young woman that transforms into a burnished mirror and briefly allows her to see an image of her ‘more beautiful’ self, subtly melding her reflection with the image of her glamorous elder sister, Susan (Anna Popplewell). Angus Bickerton shot each actress against bluescreen, establishing the performance with Popplewell, and then mirroring the angle with Georgie Henley repeating her moves. *The Senate* blended the performances into motion control elements of the book with a blue inlay. “We shot some smudging effects on a mirror,” related Richard Higham. “We added those back on top of the image with page textures. Then we animated roto splines between the two actresses, guiding the shapes into each other to warp one image toward the other. With enough keyframes, the blend was almost imperceptible and felt like a physical change.”

When Coriakin appears, he unrolls a map across the floor, displaying a three-dimensional animated image of Narnia and its outlying islands. *The Senate* generated the map as a cloth-like scroll embedded with shifting textures of animated water, islands and clouds, providing down-views of terrain that zoom and swoop about like a magical microfilm viewer.

Coriakin’s minions also become visible, not as giants, but as one-footed dwarves—known as dufflepuds—perched on one another’s shoulders. KNB initiated dufflepud designs as 2D art and clay sculptures. “Our first designs were quite fantasy-like and gnome-like,” observed Howard Berger. “But

The Dawn Treader arrives at Lone Island, an island with a central fortress settlement, known as Narrowhaven, which first appears strangely deserted. The production aimed to capture as many natural scenic vistas and sea plates as possible to provide a real-world foundation for creating fantasy environments. Toward that end, the filmmakers used a refitted ice-breaking rescue tug, which closely resembled the hull dimensions of Caspian’s ship, to conduct an extensive second-unit shoot, during which they gathered high-definition ocean plates and photographic scenic material that visual effects artists employed to create matte painting enhancements. The production filmed Narrowhaven exteriors in Australia, using a façade backed by bluescreens. Cinesite enhanced Narrowhaven scenes with digital set extensions of structures built as 3D geometry patterned after an ancient Mediterranean military settlement in Malta, then layered in scenic elements of mountains and distant sky, creating illusions of scale and parallax.

then I hit upon the idea that everything in Narnia is reality based, so I grabbed a bunch of photos off the Internet of expressive character faces, and John Wheaton did design work with those. Michael Apted liked that direction, so we searched Australia for people with amazing faces who could also act.” The production cast 14 full-sized adult male and female actors, and planned to shrink characters digitally. Makeup Effects Group lifecast the performers in Sydney, and KNB sculpted prosthetics. “We manufactured silicone cheek pieces, ears and noses. Tami Lane designed all the hair, and cut and styled wigs and beards into very whimsical and adorable characters.”

KNB created maquettes for dufflepud monopod limb configurations, and Framestore explored methods by which the diminutive dufflepuds stacked themselves into invisible giant-sized personas. Costume designer Isis Mussenden and associate costume designer Kimberly Adams-Galligan then designed dufflepud wardrobe and one-legged greenscreen breeches that performers slid both legs into to produce hopping gaits.

For scenes in which dozens of tiny hopping dufflepuds appear in Coriakin’s garden, the art department designed a storybook landscape of rolling green terrain and stylized topiary on a soundstage in Queensland. Framestore generated environment extensions and added appropriately scaled dufflepuds. “Dufflepuds were meant to be three feet, six inches high,” stated Angus Bickerton.

“Dufflepud performers were in the five-foot to five-foot-nine range, so we had to scale them down. We discussed building parts of the set oversized; but ultimately it was more practical to shoot the dufflepuds later, and then digitally shrink them.” For the landscape shoot, the production used cutout dufflepuds for reference, and dufflepud performers delivered their lines on set. “Anytime we did a shot where dufflepuds were supposed to be in view, I photographed them in costume and makeup so we had a lighting reference. We shot them individually with second unit against bluescreen for four days, and we shot a lot of elements.”

Dufflepud effects necessitated more than 1,000 photographic elements. “We roughed in animation of where we thought all the dufflepuds should be,” explained Jonathan Fawkner. “We tracked characters into shots, and that gave us a plan for what elements to shoot. There were 250 individual dufflepud performances in the cut, and we shot an average four takes of each.” Fawkner worked with dufflepud animation supervisor Craig Penn to fit performances to plates, whittling the selection down to final elements that artists tracked and affixed with monopod feet. “We built an animation rig that allowed animators to see the bluescreen dufflepuds attached to their CG rigs. We pinned them at the hips or neck, as appropriate to the shot. When we moved the CG rig around, the bluescreen element traveled with it.”



Later, the Dawn Treader arrives at another port of call, an island where Lucy investigates a magician’s library and reads from a book of spells, causing snow to fall from the vaulted chamber roof. For wide angles of the scene, Brian Cox’s team sprinkled paper snow from six stations encircling the octagonal set. For a low angle of Lucy staring up at the ceiling, Angus Bickerton positioned a greenscreen behind Georgie Henley, enabling The Senate to extend the library walls and ceiling with digital set pieces and add particlesimulation snowfall.

Framestore modeled right- and left-foot monopods and keyframe animated the limbs with muscle, skin and hair dynamics and cloth simulations for wardrobe. Final animation involved digital retimes to refine hopping motions. “We had to retain the zenith and the trough of each hop,” related Fawkner, “but if we wanted to make a dufflepud jump a bit further, the only way we could tell if it was going to work was to put the character through a blended retime in the composite. It was a very time-consuming process.” Background dufflepuds involved full-body animated characters and 2D head elements pinned to digital bodies at the neck.

The Dawn Treader takes to sea again and runs into a nighttime storm. MPC generated ocean simulations in Scanline’s fluid simulation software, Flowline. During the storm, the White Witch (Tilda Swinton), Edmund’s nemesis from the previous Narnia films, appears as a vision. Swinton enacted the scene wearing KNB makeup, supported by a wire rig, shot against greenscreen in London. Cinesite used a 3D scan of the actress to generate a matchmove of Swinton’s performance, then emitted smoky particle effects from her body and integrated her into the scene.

Lucy also experiences a vision as Aslan appears to her. Apted filmed lion scenes using a bluescreen form strapped to creature performer Shane Rangi to guide eye-lines on set. Framestore then revamped the animated character from its previous appearance in Prince Caspian. “Our brief was not to change anything,” commented Jonathan Fawkner, “but we ended up rewriting Aslan’s fur plug-ins and shaders to port them into our new system. We also rebuilt his feet because they had some very big closeups and required a lot more dex-terity.” New dynamics tools allowed Framestore to produce fully furred Aslan renders for Apted to critique with animation supervisor Mark Brocking. “Aslan had very few broad actions. He stood on his four feet most of the time, delivering dialogue. One shot was 1,500 frames long, with closeup dialogue performance, which took the best part of nine months to animate. We were able to show Michael pretty early on how we could move Aslan’s fur around, and that created much more character.”

Damaged by the storm, the Dawn Treader stops at the forbidding Goldwater Island. The production filmed establishing Goldwater scenes at White Island in New Zealand, and shot island interiors in a nearby quarry, which Brian Cox’s team rigged with atmospheric effects of volcanic venting steam. Cinesite generated digital matte painting extensions to expand the quarry into a lush, jeweled valley where Caspian and company discover a Narnian lord submerged in a pool that turns everything it touches to gold. The production created the sunken lord as a gold-painted effigy. The Senate generated effects of a magical gold coating that covers objects dipped into the pool.



The magician’s minions – who first confront the Dawn Treader crew as invisible giants – are revealed in their true form when Lucy reads a spell to unmask them as a race of tiny one-legged ‘dufflepuds’ who stack themselves like gymnasts to appear large and intimidating when invisible. KNB designed and executed silicone prosthetics and eccentrically styled hair and beards to create dufflepud makeups for 14 normalsized actors. Dufflepud performers worked against greenscreen, their legs bound together with green stockings to assist with hopping gaits. Framestore digitally shrank the actors, added monopod limbs, and blended performances with full CG background characters and environment extensions.

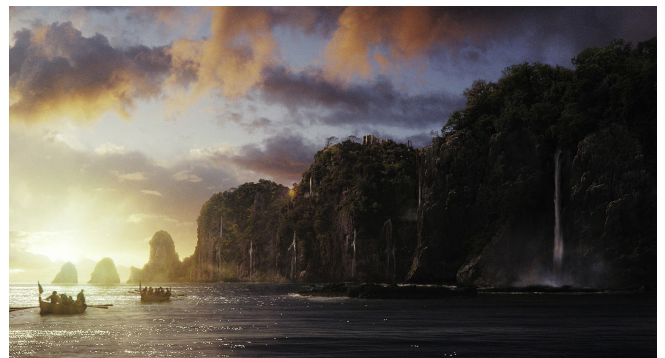
Eustace, meanwhile, wanders off and becomes lost in a jeweled valley, then later reappears, transformed into a dragon. KNB generated conceptual designs for the dragon in clay and in Photoshop renderings, depicting a classic winged fantasy creature that incorporated Will Poulter's facial characteristics. Gentle Giant Studios scanned the KNB maquette and provided the data to MPC, which adapted the design in Pixologic ZBrush to depict a 60-foot-long creature with a 52-foot wingspan. "The aim was to create a character that audiences would relate to as much as Eustace," observed Adam Valdez. "He needed to feel young, not too hard and prickly. We went for a leathery feel, like crocodile meets elephant skin. We based the pads of the dragon's paws on gorilla palms, which had a slightly human feel, but with a leathery quality that fit the creature's scale."

The production shot video of Will Poulter enacting the dragon's facial performance, but MPC relied entirely upon hand modeling and visual interpretation to imbue the dragon with the actor's personality. "Eustace is unable to speak as a dragon," commented Valdez. "We had some beautiful scenes between Reepicheep and Eustace as the dragon, where Eustace had to emote completely through his facial expressions. Gabriele Zucchelli and his animation leads did an amazing job with those scenes." The terrified dragon first clings to the Dawn Treader mast and engages in a skirmish with the crew. MPC integrated the animated creature with shots of the full-scale Dawn Treader, adding mast and sail extensions. Technical animation lead Ceylan Shekvet's team heavily augmented the ship's rigging to interact and rip apart.

The dragon then makes its identity known by seizing Edmund and carrying him inland to where it has scorched the words 'I am Eustace' into the ground. Brian Cox's team supplied wire rigs on location to lift Skandar Keynes, and bluescreen flying rigs for airborne shots. MPC tracked Keynes into the dragon's claws and used a digital double for wide shots. To complete the island's shoreline and mountainous terrain, MPC environment lead Marco Genovesi's team painted and projected scenic material in Photoshop and Nuke, which compositing lead Henry Badgett and his team blended into the environment. The dragon then flies alongside the Dawn Treader, towing the ship toward its next destination. Apted shot towing scenes using the Dawn Treader exterior motion base. MPC added



The Dawn Treader next discovers Ramandu's Island and the ruins of an ancient fortress where three of the missing lords of Narnia are found seated in suspended animation. The production captured ocean views of Ramandu's Island from its second-unit picture boat, and then constructed the cliff-top ruins as a soundstage set at Village Roadshow Studios. The Senate matte artist Doug Winder restyled the cliff face using images sampled from scenic textures shot in the English Lake District, and took inspiration from shoreline features found in Halong Bay in Vietnam. Compositors added photographic elements of the Dawn Treader crew in longboats rowing toward the island, along with details of the cliff-top fortress and elements of pouring salt for waterfalls. Stock elements of sea spray, subtle rainbow refractions and a sunset sky completed the magical effect.



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animated oars, and composited the ship into wake boat plates. For wider views, MPC used its CG ship tracked into helicopter shots.

The Dawn Treader arrives at Ramandu's Island, where Caspian and his crew seek out an ethereal entity in the ruins of an ancient castle. *The Senate* generated establishing shots of the environment in a swooping aerial perspective revealed through clouds, generated from scenic textures. For closer angles, the production built a portion of the island and its

ancient ruins. *The Senate* used a cyberscan of the set and matchmoved the footage into a helicopter plate of a coastal outcropping. "We blended our full ocean shader with bits of wake and water crashing across rocks," related Richard Higham. "We then projected that back into the sea and created fluid-simulation clouds to give us some drifting hints of mist hanging in the trees."

A brilliant light descends from the sky and takes form as Lilliandil (Laura Brent), a woman born of the stars. The production filmed interactive light effects using a 10K lamp suspended from an overhead track, which lowered into the set. Miniature supervisor Leigh Took then built a miniature tree-line rigged at a 90-degree angle on stage at Shepperton Studios, backed by bluescreen, and replicated the descending light effect using a 5K lamp on a motion control track. "We shot with the camera on its side, pointing up through the trees," explained Angus Bickerton. "As we tracked the light along, it appeared to descend through the trees. We shot bluescreen matte passes on the trees, and then smoked up the stage, which created lovely volumetric beams through the branches as the star descended." *The Senate* tracked the miniature into the full-scale set and generated a blazing sphere of light that emitted solar flares, suggesting the character's cosmic origins, then generated particle effects—emitted from a cyberscan of the actress—that resolved into Lilliandil.

Lilliandil reveals a stone table where three Narnian lords are seated in a state of suspended animation, intertwined with years of undergrowth. KNB created the sleeping lords as prosthetic dummy likenesses. "The sleeping lords were originally going to be makeups on actors," remarked Howard Berger. "They were going to have long beards and hair integrated into the vines on set, and they were going to be sitting there for a week. I suggested to Michael we should build replicas, and he challenged us to build one." Berger commissioned Jason Baird, a local effects artist and owner of JMB FX Studios, to lifecast the sleeping lord performers. "Jason did all the resculpting and moldmaking, and produced the heads in silicone. My team did all the finishing work, using stock bodies and hands. We hand-painted everything, punched all the hair, tied the beards and wigs, and rigged a bladder mechanism to simulate breathing. When we showed our prototype to Michael, he loved it!"

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The Dawn Treader follows Lilliandil's directions toward Dark Island, at the edge of the known world. MPC and Cinesite generated the environment, beginning with the ship's entry into the mysterious dome of cloud followed by a climactic action sequence within the evil mist. For establishing views, Cinesite used wake boat plates and MPC's digital Dawn Treader with extended oars that row the ship into a mass of mist. "MPC did renders of the boat that we added to our shots," noted Stephane Paris. "We created that as a 3D environment, exported in Nuke, with layers of matte paintings creating mist effects."

Inside the mist, smoky tendrils snake around the Dawn Treader crew. The production filmed mist scenes on the Dawn Treader soundstage set without practical atmospherics. "We were still toying with what the mist should look like while we were shooting," said Angus Bickerton. "We didn't know its color or lighting effects, so I favored shooting it clean. It was a big call requiring a huge wraparound bluescreen, but I knew we were going to be doing splashes and water spray, and a soft, ambient light would have made it very difficult to key off the ship and rotoscope everything on the deck." The use of bluescreen also served the film's stereoscopic conversion. "When Ed Marsh joined us as stereographer, he found the bluescreens were a godsend for creating left- and right-eye separations. It would have been a nightmare for rotoscope and compositing to post-dimensionalize scenes shot in real fog."

MPC provided Dawn Treader extensions of the ship's bow, stern and mast, which Cinesite tracked into plates with mist effects. "We created different densities of the mist," stated Matt Kasmir. "We rotoscoped every character, revealing them with a sense of movement and dynamic scale. We blended in three or four 2D fog layers projected onto spheres to help create parallax effects and a sense of depth. We had lamps creating 3D light beams to light the boat, and an electrical torch one of the characters uses, which reveals one of the lost lords in the water. We rendered 3D volumetric light beams for that with layers of mist passing through the beam and shining into camera, creating halation and starbursts. Angus gave us a lot of practically-shot lens flares and caustic elements, which looked really beautiful in the composite."

To create probing tendrils of mist, Cinesite generated Houdini particle simulations using a cylinder-shaped emission object and generated flickers of internal lighting in the tendrils, indicating a sentient intelligence as the misty tentacles crept around the ship.



While exploring the island, Lucy, Caspian and Edmund see a star descend from the sky and take the form of a young woman, Lilliandil (Laura Brent), who warns them of an evil force threatening the island. The production filmed Lilliandil's appearance by lowering a powerful motion picture lamp into the set. Mattes and Miniatures, at Shepperton Studios, then built a small-scale version of the Ramandu Island forest and filmed interactive elements of the light descending through the trees. The Senate blended the elements with a digital sphere of light that takes shape as Lilliandil's human form.

The mist manifests Edmund's fears in the form of a giant sea serpent that rises up out of the ocean and engages the Dawn Treader and her crew, including Eustace in his dragon form, in fierce combat. KNB produced clay maquettes for the sea serpent's design, incorporating a serpent body with fins and a seahorse-like head replete with jagged teeth and the soulless eyes of deep-sea denizens. Previsualization supervisor Mike Makara utilized the design to plan a serpent/dragon fight, which Michael Apted filmed on the Dawn Treader soundstage set. Principal performers interacted with practical water effects fired from six-inch air cannons, and grappled with a bluescreen form that represented portions of the serpent.

In postproduction, the 180-shot sequence took shape at MPC, which incorporated a new round of sea serpent designs by conceptual artist Stephane Levallois, which significantly altered the creature's facial design and amped up the scare factor. "We took it to another stage of nastiness," said Angus Bickerton. "When the serpent gets really mad, it opens up a hood from around its head, like a cobra—but, unlike a cobra, the hood folds back around the head revealing 200 tentacles inside. It was really quite revolting." Sam Rowan's modeling team generated two sea serpent models, the first representing the creature in its initial streamlined attack incarnation, textured with two stages of battle damage, and the second for what the crew called its 'berserker' mode, seen later in the sequence.

As part of the sequence design, MPC strove to create a connection between the sea serpent and the environment from which it has magically sprung, imbuing the evil mist with a threatening personality that surrounds the Dawn Treader. To model the nexus of the mist, MPC built giant branching pillars of fog, resembling mangrove roots hundreds of feet high, creating the impression of an underwater grotto lit with flickering green pulses of energy. The complex 3D particle structures were rendered and provided to 2D supervisor Charlie Henley and sequence lead Arundi Asregadoo, who layered elements as cards in Nuke, creating complex layouts with relative flexibility.



On Goldwater Island, Eustace wanders from the Dawn Treader landing party into an enchanted valley where he transforms into a fire-breathing dragon. KNB generated conceptual designs and clay maquettes for the dragon, incorporating elements of Will Poulter's facial characteristics. MPC used scans of the maquette and further adapted the design, using soft leathery textures and simian paws to create a creature designed to engender audience empathy. The production shot video of Poulter enacting the dragon's facial performance, but MPC relied solely on keyframe animation to communicate Eustace's wordless plight as Reepicheep takes pity on the dejected beast.



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For the serpent's interactions with the sea, fluid simulation lead Adriano Rinaldi generated ocean surfaces and splashing water effects. "Adriano's team produced a series of generic ocean caches for different intensity levels," said Adam Valdez. "As the pitch of the scene rose and fell, we had different storm levels. We also had a lot of custom simulations for the Dawn Treader and sea serpent water interactions. We used a combination of effects simulation and Nuke projections for atmospheric effects of splashes, spray and mist, creating depth and continuity across the scene."

Eustace the dragon blows fire into the sea serpent's face, causing it to plummet underwater and then emerge again, enraged. MPC generated dragon fire effects in Flowline, as well as interactive water explosions. The injured serpent, in berserker mode, wraps around the Dawn Treader, threatening to break the ship in two. MPC generated snapping timbers and crushing effects tied into practical set dressing on the full-scale set. Edmund then uses one of the magical seven swords to deliver a killing blow to the serpent, freeing the Dawn Treader. "When they defeat the serpent," explained Valdez, "we wanted it to be clear that they have also defeated the evil energy that has been plaguing them all along. So when Edmund uses his magic sword to kill the sea serpent, he kills the mist, releasing all the glowing pulses that represented its evil energy, which dissipates the cloud, revealing sunlight at the end."

After the fight, Eustace the dragon crash-lands on a beach. Brian Cox's team created a full-scale practical element for the dragon landing by hauling a bluescreen buck, shaped like the dragon's torso, behind a vehicle and dragging it 50 feet through a 1/3-scale sand bar against bluescreen on the Village Roadshow backlot. The production captured the effect on a high-speed Vision Research Phantom HD camera. MPC tracked the footage, matchmoved its dragon character to the buck and animated the creature to impact the beach and roll to a stop, with particle and fluid simulations of sand and smoke.

Aslan appears and paws the ground, causing magical energy to engulf the dragon and, in a blaze of light, restore Eustace to a boy. "In the book, Aslan empowers Eustace to tear away his dragon skin,"



Eustace is restored to human form after the skirmish with the sea serpent, and the evil mist dissipates to reveal clear skies and a sea of white lilies through which Lucy, Eustace, Edmund, Caspian and Reepicheep travel toward a nearby shore. To create the floating lily field, the production filmed a mass of plastic flowers in the Village Roadshow water tank, backed by bluescreen, and filmed actors rowing through the blooms in a dinghy towed by a winch.



MPC extended the ocean, adding CG lilies and the Dawn Treader, and replaced the sky.

recalled Angus Bickerton. “We didn’t want to be that graphic. Instead, when Aslan paws the sand, four parallel gashes appear on the dragon’s chest, from which golden light emits—relating to the dragon’s origins back in the bejeweled valley on Goldwater Island. Then, the camera rotates around the dragon as he’s ripped apart in a light show.” Kevin Hahn and Robin Huffer oversaw the transformation effects at MPC, creating glittery emissions using a combination of particle effects and Flowline fluid simulations. The effects then reveal Eustace collapsing from the blaze of light to the sand.

Eustace rejoins the Dawn Treader and accompanies Lucy, Caspian and Edmund as they row through a sea covered in white lilies toward an enchanted realm known as Aslan’s Country. The art department supplied lilies as a mass of plastic flowers fitted with a submerged keel designed to keep petals floating upward in a wind-resistant mass in the Village Roadshow water tank. Brian Cox’s team rigged a small dinghy to a winch and sailed it through a section of the lilies. MPC added ocean extensions and inserted the Dawn Treader. For more distant views, MPC generated a matte-painted floating lily field.

Eustace, the Pevensies and Reepicheep arrive at a sand bar where they encounter Aslan beside a 65-foot-tall tidal wave that stands magically held in suspension. The production filmed the scene at Jumpinpin, a white-sand promontory on the northern point of South Stradbroke Island, off the Queensland coast. “We had to keep the beach pristine,” said Angus Bickerton, “so the props crew came up with the idea to cut pieces of foam and cable-tie them to our feet, which minimized our imprint in the sand. It was a hectic shoot, with the wind whipping sand into every crevice, but it gave us real glaring sunlight and perfect miles of beach that we needed for Aslan’s Country.”

Framestore enhanced the environment by compositing calmer ocean plates into the backgrounds to help match continuity, and added photographic elements of clouds to add depth to the brilliant blue sky for the stereoscopic 3D

presentation. Framestore CG supervisor Mark Wilson then oversaw the creation of the wave as a Maya-based fluid simulation in an Exotic Matter program known—coincidentally to Narnia—as ‘Naiad,’ together with Tessendorf water displacements and sea foam textures. “The hardest thing was coming up with believable physics for a standing wave,” asserted Bickerton. “Our rationale was that as water receded from the beach, it drew up into the wave, but wind blowing into it made the head of the wave constantly break up into spray.”

Wave animation broke down into three stages. “The wave couldn’t ever break completely, or it would never be able to build back up again,” said Jonathan Fawcner. “Stage One had no white water



Aslan appears on the beach bordering his country, an enchanted realm at the edge of Narnia’s known world. To film scenes in the surreal location, the production conducted a shoot on a white sand promontory off the Queensland coast, and guided actors’ eye-lines with Aslan using a bluescreen lion form strapped to creature performer Shane Rangi. Framestore then integrated its animated character, developed for Prince Caspian but given improved fur dynamics and new articulation for the lion’s feet. Framestore also extended the environment and added clouds to create depth in the otherwise featureless sky.

on the top, and it was just about to break. Stage Two started fizzing. In Stage Three, the white water came forward and got whipped off the top by the wind. It oscillated between those three states, increasing in size and then falling back. We had several lingering shots where the cycle repeated, and that gave the wave a sense of life.”

Reepicheep elects to enter Aslan’s Country by sailing over the wave and taking his leave of Eustace and the Pevensies. MPC animated Reepicheep for the scene, which Framestore then tracked into a CG model of the mouse’s boat that traveled up into the wave and disappeared into a gentler section of the upward water flow. Aslan then roars and opens up a portal in the wave to allow Lucy, Edmund and Eustace passage home. Framestore developed low-resolution proxy simulations to block out motions of the portal in the wave, and then built up details of the effect. “We created a tunnel inside the wave by punching a hole into a volume of water,” said Fawkner. “We then made water flow out and back up the standing wave. It was a pretty complicated simulation. The final renders took a week from start to finish, on a 64-core machine, and generated approximately 10 terabytes of data.”

The portal closes behind the children in a corkscrew vortex that Framestore generated as another complex fluid simulation, inspired by whirlpool nature reference. Lucy, Edmund and Eustace then emerge back in Lucy’s bedroom, where the water recedes, leaving the three youngsters bone dry. The production filmed the scene in the submerging bedroom set, lifting the room from the water tank, and then filmed a non-motion control repeat pass of the performers in identical positions in the dry set. Framestore blended elements to reveal dry portions of the actors using animated mattes, so bodies appeared to magically dry out.

With more than 1,400 visual effects shots in the completed film, one of the major tasks for the production was to develop an efficient methodology to place visual effects tools into the director’s hands.

“Michael Apted brought a great knowledge of filmmaking to the production,” observed Angus Bickerton. “He knew how to handle the story and the characters, and he had an understanding of the technical processes; but, like any experienced filmmaker, he didn’t bother himself with the minutia of details. With the sheer scope of this project, Michael had to depend on us to provide that skill and, hopefully, creativity. He still had a big say in how everything looked, but his focus was the story. It was an epic quest, with mythological resonances and a lot of crazy, dream-like elements. Not everything was explained, but hopefully we gave it the dream-like logic it needed.”



Caspian and Aslan look on as the Pevensies and Eustace leave Narnia, walking through a tunnel in a giant wave that stands magically held in suspension above the shoreline. Framestore created the standing wave as a Maya-based fluid simulation combined with digital water displacements and sea foam textures. The wave animation oscillated through three stages so the crescent wall of water would appear to constantly rise, decay and replenish. To model the tunnel in the wave, MPC punched a hole into the volume of water and directed water flows through render intensive fluid simulations.

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The Last Enemy

image

By Joe Fordham

At the conclusion of his sixth year at Hogwarts School of Witchcraft and Wizardry, young wizard-in-training Harry Potter (Daniel Radcliffe) was in trouble. His principal benefactor, Hogwarts headmaster Albus Dumbledore (Michael Gambon), was dead; and his nemesis, the Dark Lord Voldemort (Ralph Fiennes), was preparing for global domination, protected by a spell that split his evil soul into seven pieces, known as Horcruxes. Harry's quest to destroy the Horcruxes and vanquish Voldemort formed the basis for *Harry Potter and the Deathly Hallows*, the final volume of J.K. Rowling's seven-novel fantasy series.

To adapt the novel to the screen, closing out their film franchise, producers David Heyman and David Barron re-teamed with screenwriter Steve Kloves and director David Yates, and decided to turn the narrative into a cliffhanger, presenting it in two films that would be released eight months apart. "It was a huge challenge to shoot two films at the same time," stated the production's four-time visual effects supervisor Tim Burke. "Compared to previous films, we were handling twice as many shots, many of which required elements that needed turnover before the end of production. In some instances, we were unable to get actors together on the same set at the same time, so we occasionally shot characters against greenscreen and later dropped them into scenes. It was a scheduling nightmare."

Burke assembled a previsualization team led by animation supervisor Ferran Domenech to create animatics of action sequences for both films, while production designer Stuart Craig simultaneously plotted new set builds at Leavesden Studios and Pinewood Studios. Harry's quest, roving rural Britain, involved mixtures of locations and soundstage work. "We didn't have the resources to shoot in all the locations Harry visited," Burke commented. "Instead, we shot actors on partial backlot sets, and then our visual effects crews went out to places that Stuart had scouted, like Malham in Yorkshire and Battleton Moor in Somerset. We shot high dynamic range digital stills of those environments, re-projected them as textures and rebuilt geometry where necessary to extend the sets."

To wrangle logistics of the 18-month shoot, Burke regrouped with visual effects producer Emma Norton and divided on-set duties with visual effects supervisors Chris Shaw and John Moffat. "Emma did a brilliant job managing finances and production schedules," Burke observed. "Chris Shaw has worked on more Potter films than I have—he was on the first one, and moved up from being a technical on-set person to co-supervising the filming. His specialty is motion control, programming rigs and motion bases, so he oversaw complex shots and second-unit action scenes. John Moffat joined us on the sixth film; and he was a great asset, so I asked him to return, working mostly on first unit. At one point, we had three motion control rigs shooting at the same time, in addition to first and second units."

Schedules and efficiencies among visual effects vendors caused the production to allocate some previously established magical characters and effects to new effects houses. Rising Sun Pictures, for

example, which had created animation on past Potter films, picked up the dementors—originally the work of Industrial Light & Magic—and Voldemort’s face enhancements, previously done by The Moving Picture Company, this time went to Cinesite. “MPC held onto Voldemort’s snake, Nagini,” observed Burke, “who had a massive part in this story. MPC picked up the thestrals, as well, which traditionally ILM had done.” Potter veterans Double Negative, Framestore and Baseblack also returned to contribute key effects shots to the series’ finale.

To provide practical mechanical effects, including performers riding flying creatures, special effects supervisor John Richardson drew on his catalog of motion base rigs perfected since the beginning of the series. “Our new flying rigs made life a lot easier with the opening of Part One,” remarked Richardson. “We had a pretty intensive chase sequence, with several characters airborne, and our new rigs enabled us to put actors on a flying motorbike and sidecar, as well as Voldemort and his Death Eaters on broomsticks.”

Also returning for the finale was Nick Dudman’s creature effects team, which embarked on extensive maquette production for the multitude of creatures to appear in *Deathly Hallows: Part Two*, and provided makeup effects for several key characters in Part One, including *Harry Potter*’s chubby stepbrother Dudley Dursley (Harry Melling). In the years since Melling’s last appearance, in the fifth Potter film, the actor had shed Dudley’s puppy fat. “Harry Melling was now a drama student doing dancing and ballet, and he was covered in muscle!” stated Nick Dudman. “He no longer looked like Dudley, so we lifecast him, dug out reference images of what Dudley used to look like, and sculpted him back to how he was.” Dudman’s fabrication team, led by Janet Burns, oversaw creation of a weighted fat suit for Melling to wear under his costume, while key prosthetic makeup artist Mark Coulier sculpted prosthetics around the jowls and neck, ending under the eyes and extending to the chest. Dudman’s team cast appliances—and the majority of prosthetics and likeness dummies for the film—in platgel silicone.

The film opens with Hogwarts student Hermione Granger (Emma Watson) taking leave of her parents and protecting them from Voldemort by erasing herself from their memories using an Obliviate charm. “It had to be a subtle effect because it was a very poignant moment,” said Baseblack visual effects supervisor Matt Twyford. “We created a ghostly 2D displacement on the parents’ facial expressions and a misty swirl that sucked back into Hermione’s wand. It was stylistically reminiscent of the pensieve memory effects seen in earlier films.”

A title sequence follows, beginning with the Warner Bros. logo and main title appearing from clouds and corroding as they approach camera. Double Negative rendered clouds in its fluid dynamic software, dnSquirt, then generated 3D graphics with a pewter patina and applied corrosion as painted textures blended to the models using procedural maps. The camera then dives down to reveal aerial photography filmed over woodland surrounding Hardwick Hall in Derbyshire.

Rising Sun Pictures modified the Elizabethan building, starting with high dynamic range images of the structure to create the pointed gothic rooftops of Malfoy Manor. The smoky form of a Death Eater swoops toward the manor gates and takes human form as Hogwarts headmaster Severus Snape (Alan Rickman). RSP generated Snape's airborne apparition using a custom cloth simulation developed in Houdini. "We referenced Death Eater effects that Double Negative did in earlier films," noted RSP visual effects supervisor Sean Mathiesen. "The brief was to give Snape a distinctive character, so we made him a smoky cloth-like bat creature that he emerges out of as he lands."



Teenage wizards Harry Potter (Daniel Radcliffe), Hermione Granger (Emma Watson) and Ron Weasley (Rupert Grint) are forced into hiding in the seventh film of their adventures, Harry Potter and the Deathly Hallows: Part One, based on J.K. Rowling's immensely popular literary creation. The producers and director David Yates dramatized Rowling's seventh novel as two films, shot back-to-back and released eight months apart. Special effects supervisor John Richardson and makeup effects supervisor Nick Dudman re-teamed with visual effects supervisor Tim Burke, who then wove together magical events with visual effects artists at seven vendors based in London and Adelaide

Snape enters a hall where Voldemort has Hogwarts Professor Charity Burbage (Carolyn Pickles) suspended in zero gravity over a banquet table. John Richardson's team suspended the performer against greenscreen, and Baseblack then composited Burbage into the scene. Ralph Fiennes performed Voldemort wearing a combination of practical and digital prosthetics. Voldemort's practical makeup involved a shaved head, which key prosthetic makeup artist Katy Fray executed each morning. Mark Coulier and prosthetic artists Duncan Jarman and Stephen Murphy then applied platgel prosthetics to cover Fiennes' brows, subtly modifying the actor's forehead and creating a deep eye-socket effect. Tattoo transfers created veining over the cranium with an unhealthy chicken-skin texture. Dudman's team then applied horny fingernails, dental prosthetics, contact lenses and airbrushed shading, and employed a vacuformed face template to locate tracking dots, which Cinesite referenced to affix Voldemort's snake-like snout.

Cinesite rebuilt digital portions of Voldemort's face from a cyberscan of Fiennes' head and a texture shoot of the actor in makeup. "The textures were shot polarized and unpolarized so we could extract specular maps for pore details," stated Cinesite 3D supervisor Holger Voss. "We created displacement maps from the cyberscan, then updated a skin shader to work with the model, mainly using a diffused texture based on the cross-polarized images, plus specular maps, bump maps and light reflectance albedo maps for subsurface scattering. We rendered Voldemort's full head, and then used sections in the composite."

Eight markers on Fiennes' face and another eight on his head allowed matchmove artists to track the CG head and blend the digital muzzle. "We tried to retain as much of the live-action as possible," explained Cinesite 2D supervisor Andy Robinson. "We matched Ralph Fiennes' vocal performance to create upper lip motion and animation surrounding the nose, and we varied the blend from shot to shot. The CG prosthetic extended from between the eyebrows down to the upper lip. We kept as many natural facial creases as possible, and used our CG skin textures to remove shadows of Ralph's real nose."

Voldemort orders his giant snake, Nagini, to dispose of Burbage. Gary Gero's Birds & Animals Unlimited supplied a python as reference for the CG creature that MPC redesigned to represent a biologically realistic snake. "The old Nagini resembled a python crossed with a green anaconda," recalled Tim Burke. "Our new Nagini was much more like a real python. However, David Yates wanted her to display quite an evil character, so we redesigned her eyes using reference of other types of snakes. We brought up her brows and made her eyes a little more slitted."

The new Nagini required complete re-rigging and texturing. "We created translucency and blue-green iridescence along her body," observed MPC visual effects supervisor Nicolas Aithadi. "We outlined every scale on her body and rewrote the shader to incorporate all of those displacements. It was similar to a human skin shader, but with different types of subsurface scattering, and two or three types of stickiness. Snakes are glossy, but they're not wet. We tried to strike a balance between those qualities by separating the sheen into different types of reflections and specularities." MPC articulated snake motion by constricting and sliding rings of muscles. "Nagini sometimes moved like a python, sometimes like a viper; and sometimes, when she held her head high, she was like a cobra. In those cases, we had to scrap the python dynamics and use other types of snake motion with the same kind of musculature stretch, but different muscle groups."

Back in the non-magical muggle world, witches and wizards arrive at the Dursley home to escort Harry to a safe haven. The production filmed the scene on the suburban street set at Leavesden, with horses standing in for skeletal winged thestrals. "We used a couple of horses to approximate the thestrals' height and position," said Tim Burke. "They had a little bit of agitation in their movement; and when we rotoscoped them, it gave us a great starting point for the creatures' movements."



The Dark Lord Voldemort (Ralph Fiennes) holds court at Malfoy Manor with a retinue of his Death Eater acolytes. Nick Dudman's makeup effects team reprised prosthetic makeups that they had devised for Fiennes in previous Potter films, shaving the actor's head and applying platgel silicone prosthetics and tattoo transfers to create veining effects.



Cinesite then used tracking marker dots on the actor's head to affix digital prosthetics, adapted from work executed in earlier films by The Moving Picture Company, and used a new texture shoot and cyberscan of Fiennes to create a flattened snake-like muzzle.

MPC created thestrals by adapting textures and geometry that Nick Dudman's team and ILM had created for the fifth and sixth Potter films. "ILM very kindly gave us everything they had," remarked Nicolas Aithadi. "We used proprietary shaders, so we had to create our own textures by studying thestral shots in *Harry Potter and the Order of the Phoenix*. We ended up creating the color map ourselves. We used some of ILM's displacements, and for two closeups we added a little more skin detail and wrinkling." MPC revamped thestral physiques to accommodate pairs of riders. "We studied pictures of Nick Dudman's full-scale maquette and the cyberscan that had come from that. We scaled the thestral 15 percent taller, made the wings a bit more muscular, and moved them forward, above the creature's shoulders."

Harry's friend, the oversized Rubeus Hagrid (Robbie Coltrane), lands astride a flying motorcycle and sidecar. The special effects team built a series of practical prop motorcycles, based on a 1959 Triumph Bonneville. "I was concerned that we weren't going to be able to find the number of matching roadworthy Triumphs that we needed," noted John Richardson, "so we used replica 1960s bikes that were manufactured in India. The company who supplied them also supplied the sidecars, and we rebuilt them to suit our own design." Richardson's team built seven motorbikes, one of which was rigged to fit a motion base. "The bike was human-sized so Daniel Radcliffe could sit in the sidecar while the large-scale Hagrid double sat on the saddle. Visual effects then either split the two, or did face replacements where needed."



For the Dark Lord's giant snake, Nagini – who would play a significantly greater role in the new film – The Moving Picture Company revamped the digital model it had generated for previous films, devising a more biologically realistic appearance based on nature reference. MPC re-rigged and re-textured the creature with detailed snake scale displacements and a glossy, iridescent sheen. Animators then articulated the snake to exhibit behaviors based on those of pythons, vipers and cobras.

Before Harry's escort takes flight, six witches and wizards—Hermione, Ron Weasley (Rupert Grint), Ron's twin brothers (James and Oliver Phelps), the glamorous Fleur Delacour (Clémence Poésy) and the elderly Mundungus Fletcher (Andy Linden)—drink shape-shifting polyjuice potions that disguise them as Harry doubles. MPC created transformations using motion control passes and Mova Contour Reality Capture, a high-resolution facial capture system based on applications of colorless ultraviolet pigment. "We'd become a bit frustrated with facial capture techniques on earlier Potter films," confessed Tim Burke. "But we'd seen the work that Mova had been doing with UV makeup, with the potential for capturing up to 100,000 points of information from a facial performance, and it seemed like a useful way of handling polyjuice transformations. David Yates was keen to make viewers believe that, although we were looking at characters transformed into Harry, the personality of the person inside each hybrid still came through."

To shoot the six hybrid Harrys, each performer first enacted his or her transformation. Daniel Radcliffe studied each performance and repeated the moves, filmed by motion control, and then performed repeat passes for Harry group shots. "We ran up to 10 or 11 takes until Dan nailed the characteristics of each hybrid," said Burke. "When it came to Dan performing Hermione as Harry,

Dan knew Emma Watson so well, he went right into character and got it in one take.” Further complicating the scene, each character changed clothes as their bodies transformed. “We had shots where Dan was playing Fleur as she was getting undressed, so her body was a young man’s body, but she was still wearing her bra. Dan had to remove the bra and hand it to Fleur’s fiancé. It was very funny, and Dan did a stunning job.”

The Mova team next set up a capture booth at Leavesden where actors wore UV makeup while David Yates directed facial performances and Tim Burke’s team captured backup material from three HD witness cameras. MPC then used the 3D data to construct photorealistic digital models of each performer, and designed transitions in Photoshop. “We copied and pasted pieces of the actors’ faces with Harry’s,” said Nicolas Aithadi. “The real challenge was to translate that into 3D. Mixing around the features, we realized that George and Harry didn’t have the same size head, so we had to decide if we were going to keep Harry’s size for everybody, or keep each character’s original sizes.”

MPC lead rigger Dan Zelcs used Harry’s head as the main template and worked with the effects team to blend details and skin transitions. “Harry is very pale and a couple of characters were quite tan,” observed Aithadi. “With Mundungus, we decided it was more interesting to keep the skin tones of the older character, but we changed the face to make it look like Harry. It took six months to plan all the transitions, rigs, lighting and shading. I never thought eyelashes would cause so much grief! We found that if lashes were a bit longer or shorter than they were supposed to be, the character was no longer the same character. We tried to make the transitions fun—noses and ears got big, for example—but we kept them as photoreal as possible.”

Broomstick riders and thestrals take to the air over Privet Drive, with Hagrid and Harry, in the motorbike and sidecar, bringing up the rear. John Richardson’s team hung the motorbike from a crane, practically flying the bike and riders on set for takeoffs and landings. For wide shots, stunt coordinator Greg Powell rode the motorbike wearing an oversize Hagrid suit and head, the latter fashioned by Janet Burns’ fabrication team.

MPC generated a digital model of the motorbike and riders for wide shots of Hagrid and Harry following other riders into clouds and emerging into furious aerial combat with 30 Death Eaters. Aerial backgrounds featured volumetric rendered clouds and live-action textures. “A lot of our aerial shots had 95 percent CG clouds,” said Nicolas Aithadi. “We incorporated photographic elements, composited in Nuke, which allowed us to move planes of clouds to create 3D effects in 2D space. That helped reduce the ‘curse’ of CG and was more efficient than rendering full 3D clouds.”



A contingent of wizards and witches arrives at Harry Potter’s home and uses a polyjuice potion to transform six of their number into duplicates of Harry in an effort to confuse Voldemort’s followers while they whisk the real Harry away to a safe haven. The production used motion control, compositing and a Mova Contour facial capture system to create polyjuice effects. Hybrid Harry performers enacted their transformative contortions, and then Radcliffe stepped in to film repeat passes. MPC used Mova data to build 3D models that transformed from each actor into Harry clad in the hybrid characters’ costumes.

Practical 2D elements included riders in flight that second-unit cinematographer Mike Brewster filmed with performers on motion control rigs against bluescreen. *Flying* rigs interfaced with animation using Mark Roberts' Flair motion control program, while EMP Designs furnished electronic equipment to run motion bases and motors. MPC then integrated animated Death Eaters and wand effects with bluescreen riders. "On previous Potter films," remarked Aithadi, "if flying characters weren't close up, we would jump into digital. This time, most of the shots of Harry and Hagrid in the sky were real. We only switched to digital doubles when camera moves were very dynamic." Hagrid uses his 'dragon-fire' supercharger to exit the battle, heading down to ground level with three Death Eaters on his tail. MPC generated dragon-fire as a Flowline fire simulation tracked to the motorcycle's tailpipe.



As Harry's escort prepares to leave his foster parents' home, Fleur Delacour – disguised as Harry – grips onto her fiancé, Bill Weasley (Domhnall Gleeson), astride a skeletal winged thestral. For land-based thestral scenes, the production shot actors on horseback to approximate the magical creature's height and gait. MPC then generated thestrals as digital creatures, making use of designs that had originated with Nick Dudman's team and a digital model generated at Industrial Light & Magic on the fifth Potter film. MPC accommodated two riders by scaling up thestral anatomy and beefing up musculature of the creature's wings.

The chase continues with Death Eaters pursuing Hagrid and Harry through traffic, smashing into a caravan and speeding through a crowded commuter tunnel. The hair-raising sequence required several months of previsualization to plan shooting in three locations. For the tunnel approach, the production dressed a portion of RAF Bovingdon airfield to simulate an English motorway. Lighting fixtures suspended from cranes illuminated stunt doubles weaving through traffic on stunt bikes. MPC used location textures shot at the Dartford Tunnel in east London to augment backgrounds, added vehicles and swooping Death Eaters and created the caravan explosion as a rigid body dynamic simulation.

The explosion causes Hagrid to swerve into oncoming traffic. Production filmed the sequence over four nights at Dartford, and then shot tunnel interiors in the Mersey Tunnel in Liverpool. MPC added vehicles and modified the environment to enhance the chase. "The four-lane-wide tunnel interior didn't look dangerous enough," observed Nicolas Aithadi. "So we turned it into a two-lane tunnel. They shot only on two lanes, and we rebuilt the interior tunnel walls digitally. In almost all of the shots, we retained only the road and cars, and the whole environment was digital."

Closeups involved greenscreen elements of Hagrid and Harry on the flying motorbike, rigged to swoop and swerve and, at one point, invert as Hagrid avoided collision by steering up the wall. "We had the bike on a rollover rig in front of greenscreen," explained John Richardson. "It was pole-arm-mounted about 16 feet in the air. The pole could either go into the back, between the sidecar and the bike, so it could roll sideways, or we could mount it coming out 90 degrees from the side and revolve the bike end over end." Performers sat on Kevlar saddles and padded fiberglass shells clipped to safety straps. A Moog electric actuator controlled a chain-driven electric motor that provided pitch, yaw and rotation.

MPC used digital doubles for wide shots of Harry, Hagrid and their motorcycle riding up the wall, allowing integration of bike wheels with tunnel surfaces. As the last Death Eater closes in on Harry, Hedwig the owl swoops in to his defense. “We got a couple of shots with a real owl against greenscreen,” noted Tim Burke. “The animal handler had the owl fly and land just above the camera so it felt like she was attacking the Death Eater with her talons out.”

MPC integrated the greenscreen owl into plates, speeding up the bird’s motion. “We retimed the element so it felt like Hedwig was flying full-speed at the Death Eater rather than meeting her trainer,” stated Nicolas Aithadi. “For the next angle of her attacking the Death Eater, they shot the bird and actor separately, which worked perfectly. We then had two shots where Hedwig swung around and got hit by a wand blast. We were already manipulating a 2D element of Harry and Hagrid in that shot, and a 2D element of the Death Eater, and it was too constricting to retime a third element; so we scrapped the live bird and replaced it with a CG owl, which gave us more control. We then animated Hedwig falling. We added a couple of flying feathers, but tried to keep Hedwig’s death discreet.”

Alerted by Harry’s reaction to the loss of his beloved owl, Voldemort swoops in as a powerful smoke-like presence. Ralph Fiennes, in full makeup, performed flying scenes against greenscreen on a motion base, reclining on a panel fitted to his body beneath his robes. Fiennes also performed Mova facial capture for the scene. Cinesite generated a nose replacement for one shot and, for the remainder of the flying Voldemort shots, MPC integrated its own facial model with effects that suggested the Dark Lord’s mercurial smoky form. “We wanted the smoke to feel alive and menacing,” observed Aithadi. “It had to feel like Voldemort was the smoke, not just emitting vapor. We used cloth simulations for his robe, but allowed surfaces to penetrate one another and made the cloth billow like smoke.”

Harry duels with the Dark Lord as Hagrid navigates a field of electrical towers. MPC generated the environment based on a tower array in Southend-On-Sea, Essex. “The pylons were very dramatic and added an extra element of danger to the scene,” said Tim Burke. “When Harry and Voldemort’s wand spells collide, they create huge explosions, which throw Voldemort back. Then, in a huge hissy-fit of rage, Voldemort sends out a shockwave that knocks down the pylons.”



The real Harry climbs into a motorcycle sidecar steered by his friend, the half-giant Rubeus Hagrid (Robbie Coltrane), and takes to the air in the magical machine, following the other riders. John Richardson’s team used a series of replica motorcycles modified to resemble a 1959 Triumph Bonneville to create seven versions of Hagrid’s motorcycle utilized for hero performances, stunt riding and effects rigs. For wide shots, stunt coordinator Greg Powell rode the motorbike wearing an oversize Hagrid suit and head that Nick Dudman’s team created to fit over a crash helmet.



MPC generated the towers as 3D models using photographic surveys of the location, then did volumetric clouds and wand effects, including jagged electrical effects that ripple through Voldemort's vaporous form. MPC built its environment using scenic textures and digital matte paintings of villages extending out into the horizon. As the power lines fall, the lights in each village extinguish.

Harry's head is added to the digital performance of his stunt double, and the ground under the motorcycle is replaced by a digital ground plane. The digital ground plane is used to create the motorcycle's path through the forest, and the digital ground plane is used to create the motorcycle's path through the forest.

After evading Voldemort, Hagrid crash-lands into the reeds at the Weasley Burrow, rebuilt since its destruction in the previous movie. The special effects team rigged the crash on a backlot set at Leavesden, with the bike riding along a 160-foot-long track. "We did the crash at speed into water," said John Richardson, "which sent up a huge splash. David then asked us to make the bike hit the water, bounce and go back down again. We did that by cable-rigging the bike on a skate that rode down the track. We fed the motorbike tires into little guides that held the weight of the bike and made the wheels revolve correctly. We then rigged a cable loop to pull the bike along using a big four-wheel-drive pickup. My son Marcus did all the driving for that because he's a good, trustworthy driver, and I knew he'd get the maximum speed, and stop accurately at the end."

For shots of the motorbike careening over the Burrow, MPC generated a CG bike with Harry and Hagrid digital doubles, and CG water splashes. For shots of the bike's impact with the ground, and subsequent scenes around the Burrow, Double Negative integrated 3D rolling hills and paths that led off into marshland. "The scenes at the Burrow were seen in several different lighting styles," said Double Negative visual effects supervisor David Vickery, "so we needed full 3D environment extensions. We created reed-bed extensions using a mixture of 3D geometry and paint effects, run through Houdini dynamic simulations to bend and deform them. We had to create several million reeds in 40 or 50 shots, so we rendered 2D elements with different reed layouts and motions, and projected those onto cards. We set up scenes in Shake, positioned as two-dimensional cards in three-dimensional space, then plugged in the elements, which automatically arrayed themselves in the environment."

As other survivors arrive back at the Burrow, Harry hybrids revert to natural appearances. Double Negative handled environment extensions, while MPC generated polyjuice transformations using Autodesk Flame morph effects. George Weasley returns minus an ear, achieved as a makeup. "We made a hard plastic cover to hold down the actor's ear," explained Nick Dudman, "and we then put a soft silicone prosthetic over that. We sculpted the prosthetic to cover the side of George's head down to his neck, building out the side of the head, which made the wound look quite deep without a digital effect."

In the safety of the Burrow, Harry and his friends prepare for their quest. Hermione packs a small handbag that magically contains oversized props. "Hermione's bag was an old smoke-and-mirrors gag," observed Tim Burke. "We had a bottomless bag that, when needed, had a green bag attached. Emma could put her hand through the bag and pull out larger props as if they were coming from an invisible space inside. We then digitally removed the green bag and replaced the bottom of the bag.

Other times, we did an even simpler trick: we had a bottomless bag and people handed props from the bottom of frame. A couple of times we had the bag sitting on a table with a hole through it, or on the ground with a pit underneath.”

Minister of Magic Rufus Scrimgeour (Bill Nighy) interrupts the young wizards’ preparations to present them with Albus Dumbledore’s last will and testament—a magical scroll that unrolls and floats in midair, generated as a 3D animated effect at Baseblack. Dumbledore bequeaths three obscure objects as clues to help locate the Horcruxes. Ron receives a deluminator—a small object resembling an antique lighter, which, when clicked, magically removes or restores light in an environment. The production filmed deluminator scenes with illuminated and darkened lighting passes, and then Baseblack animated transitions. “We did different deluminator effects for different scenarios,” explained Matt Twyford. “In the Burrow set, Tim supplied us with interior soundstage plates with bright daylight in the windows, and lamps in the set turned on and off. We then matte-painted light sources and revealed them on the fly as the light moved over the characters as if a spell was physically pulling the light out of the scene into the deluminator.”

Hermione receives a book of children’s fairytales, and Harry receives a Quidditch snitch—a metallic winged sphere that sprouts wings and takes flight. Baseblack modeled the snitch from practical props— wings open, wings furled—and animated the sphere to flit around, agitating Harry as he attempts to learn its secrets, which remain elusive.

The Weasley family meanwhile prepares for the marriage of Bill Weasley and Fleur, but the wedding is interrupted when shocking news arrives via a glowing patronus charm from Senior Auror Kingsley Shacklebolt (George Harris) warning that Voldemort has assumed command of the Ministry of Magic. Double Negative generated the patronus as a pulsing ball of energy built around a practical lighting effect. “The electrical department built a large box covered in LEDs,” related Tim Burke. “We recorded Shacklebolt’s voice in advance, and the intensity of the voice drove the brightness of the LEDs. The actors could hear the dialogue playback as the voice made the LEDs pulse, which Double Negative then replaced with a beautiful patronus effect.”

Unlike patronuses in previous films—depicted as glowing animal spirits—Shacklebolt’s patronus was realized as a magical emergency transmission. “Our concept artists produced designs of an ethereal, almost optical effect,” related David Vickery. “It started as a star-like point of light, then crashed through the wedding tent and unfurled into a ball of light with tendrils reaching out. David Yates suggested that the patronus should project a montage of imagery from the Ministry. Chris Shaw shot some stunt guys dressed as Ministry of Magic employees running about. We turned those into distorted projections coming out of the patronus light. We did most of that in Maya and Houdini, with cloth-like light simulations and elements of mist



Having evaded the Death Eaters, Harry hides out at the Weasley Burrow – Ron Weasley’s rural home, rebuilt since its destruction in the previous Potter film – which serves as a magically protected retreat for a congregation of witches and wizards that gather for Bill’s and Fleur’s wedding. Production designer Stuart Craig built the

and steam. We also generated a dry-ice effect on the surface of the sphere, using simulations in DNB and Squirt, which made the patronus feel like a tactile object.”

resurrected Burrow on Leavesden Studios’ backlot as a partial full-scale set that extended to the first floor and was backed by greenscreen. Double Negative supplied enhancements, topped the set, integrated surrounding marshland, and added extensions to the wedding party marquee and a tented walkway.

Three Death Eaters burst into the tent as smoky plumes that Double Negative generated in Maya using Squirt and Houdini. “Death Eaters contained three components,” said Vickery. “The main smoky column represented the disguise that the Death Eater hid behind. Inside that were threads of procedural cloth simulations that represented Death Eater capes winding through the smoke. We did a lot of work to generate new ways to control those simulations. We then added 2D rippling and distortion to create the sense that Death Eaters were displacing the air and interacting with the environment.”



The wedding party is interrupted when a patronus charm arrives in the form of a glowing spherical orb of energy dispatched to warn revelers that Voldemort has forcibly taken control of the governing body of the Ministry of Magic. The production filmed a pulsing interactive light effect on set to represent the patronus light illuminating the tent interior. Double Negative then digitally removed the prop and replaced it with a sphere of light that emitted glowing vaporous tendrils and revealed glimpses of terrified Ministry employees, created using digital projections of greenscreen elements.

Harry, Ron and Hermione disapparate to London, where they encounter two more Death Eaters in a cafeteria. The production filmed the café interior on a Leavesden stage with bluescreen outside the set windows. Baseblack inserted digital stills of the Soho exterior and greenscreen elements of cars and people passing by. The special effects team then rigged the cafeteria set with practical effects to simulate wand hits as Harry and his companions duel with the Death Eaters. “David Yates wanted a lot of violent spell hits for the café fight,” said John Richardson. “We smashed up the tables and did a lot of squib hits. The effects were similar to bullet hits, but bigger and flashier.” Baseblack then added 2D flashes, debris, smoke, shockwaves and a deluminator effect that Ron triggers to cover their exit from the scene.

The young wizards escape to 12 Grimmauld Place, a London safe house protected from Death Eaters by a Fidelius charm. The production made use of establishing shots of the house and its magical camouflage, reusing effects created at Rising Sun Pictures for the fifth *Harry Potter* film.

Inside the house, an automated spell greets Harry and his companions as an apparition of Albus Dumbledore warding off intruders. Tim Burke filmed Michael Gambon for the apparition. Cinesite referenced the footage to generate an agglomeration of dust that formed Dumbledore’s ghost. “We built a digital double and projected Gambon’s greenscreen performance onto that,” explained Holger Voss. “We matchmoved the performance and used the textures to drive particle simulations. The shot depended on not revealing too much of Dumbledore too early. The lighting was quite moody, so we used two hot lights in the corridor to make him silhouetted and backlit.”

To assist in his search for the Horcruxes, Harry summons Kreacher, the recalcitrant house elf, and Dobby, his own freed and retired house elf from Hogwarts. Framestore generated house elves as keyframe-animated characters derived from existing designs and from reference provided on set by voice actors Simon McBurney and Toby Jones. “I convinced David Yates that the people providing Kreacher’s and Dobby’s voices should be present for shooting,” commented Tim Burke. “When we brought in Simon, he crouched down to almost Kreacher’s true height, getting into character. Toby took a lead off that and did the same, and they stole the scene. As David worked with them, I could see him getting really excited by the process.”

For interactions of house elves grappling other characters, small-stature stunt performers followed the voice actors’ lead. “We filmed rehearsals with Simon and Toby in shot,” Burke explained. “We then set up capture areas off to the side of each set, with a couple of HD cameras focused on each actor, and had them deliver dialogue as we filmed principal performers with our size doubles. The little people on set followed the performances that Simon and Toby had established, hitting the same marks and providing eye-lines. After that, David directed studies of Simon and Toby in our capture booth, running them through their facial performances. We handed all of that material to David’s editors, and when they delivered sequences back to us, we knew what David wanted from Kreacher and Dobby in every shot.”

Framestore translated the reference material into its animated characters, reengineering the Dobby model that ILM had originated on the second Potter film and updating their own Kreacher model from the fourth and fifth. “We used Kreacher’s and Dobby’s same topologies but gave them both a makeover,” said Framestore CG supervisor Andy Kind. “We built on our recent skin shading technology, using multiple subsurface scattering techniques.”

The production pushed house elf designs into somewhat more humanized renditions of the scrawny little characters. “David wanted the audience to connect emotionally with the house elves,” said Framestore visual effects supervisor Christian Manz. “The on-set reference was invaluable, but we didn’t use that to do performance capture or roto-animation. It was based more on observation.” Reference included photo and video studies of Barry Penberthy, a Framestore staff-member who posed as life model for the coloration and motion of Kreacher’s eyes.

Kreacher’s personality comes to light as Harry cross-examines the house elf about his previous master’s involvement with the Dark Arts. “Kreacher is very jaded and secretive when we first see him,” said Framestore animation supervisor Pablo Grillo. “When Harry corners him and forces him to open up, we begin to sense Kreacher’s conflict as he searches for his answers, with small darting movements of his eyes showing the anxiety of an old man in pain.” Framestore animated expressions using pose-based deformations in its Facial Action Coding System of blend shapes, based on Doctor Paul Ekman’s behavioral analysis of facial muscular movement. The physical disparity between small stunt performers and house elf physiques required broader interpretations of body language, followed by secondary animation of dynamic muscle jiggle, skin slide, and interactive hair and cloth simulations.

3D tracking played an important part in character interactions when Kreacher and Dobby capture Mundungus Fletcher and apparate with him into Grimmauld Place, wrapped around the elderly wizard's legs and head. "The two small stunt actors sold the weight of Mundungus' performance," stated Framestore 2D supervisor Christian Kaestner. "But the stunt performers were significantly taller and larger than Dobby and Kreacher, so we had to do a huge amount of work to paint out the small actors and re-track Mundungus. We then bumped that back into our lighting pipeline to get our animation and lighting working with our painted elements."



Harry, Ron and Hermione flee the wedding party, taking shelter in a wizard safe house at 12 Grimmauld Place, in Central London, where they encounter an apparition of Hogwarts' deceased headmaster, Albus Dumbledore (Michael Gambon), that rises up out of the dust. The production filmed an element of Gambon enacting the scene against greenscreen. Cinesite referenced the footage to create a 3D digital double of the character, which they projected with the filmed textures. The model drove particle simulations of dust that Cinesite animated to rise from the floor and stream upward into the eerie character.



Harry summons Kreacher, guardian of 12 Grimmauld Place, and forces the grumpy house elf to aid him in determining the whereabouts of the Horcrux, a magical locket containing part of Voldemort's splintered soul. The production filmed house elf scenes using voice performers to deliver lines and establish blocking on set, and filmed takes using small-stature stunt players. Framestore then generated Kreacher as an animated character, refining his appearance and dexterity from previous Potter films.

With Kreacher's help, Harry, Ron and Hermione determine that one of the Horcruxes is being held at the Ministry of Magic, which they infiltrate using polyjuice potions to adopt the identities of three unsuspecting Ministry employees. Rising Sun Pictures generated polyjuice transitions as morphs between performers, and RSP sequence supervisor Nick Epstein created enhancements of Ministry interiors, adapting set extensions that MPC created for the fifth Potter film to reflect Voldemort's rise to power—including the addition of a giant statue in the atrium. "The statue was 50 percent a real build on set," said Sean Mathiesen, "but we extended that and added it to shots. The design was of a witch and a wizard standing together on top of the oppressed muggle masses. From that concept, we built a digital model. The art department made a small-scale sculpture from that, which they cyberscanned and sent back to us. We rebuilt our model to the art department cyberscan and then textured that from photo references."



Framestore also generated Harry's loyal house elf, Dobby, giving him a digital makeover for his heroic final appearance in the Harry Potter saga.

Harry infiltrates a courtroom where he encounters Senior Undersecretary Dolores Umbridge (Imelda Staunton), who wears the Horcrux as a pendant around her neck. RSP generated courtroom extensions to transform the partial set into a tall vaulted chamber, and then added spectral ghostly dementors—skeletal forms wreathed in floating robes—adapted from designs in previous Potter films that had originated with Nick Dudman's team and ILM. "Our sequence supervisor, Mark Wendell, based our dementor characters around Maya Cloth," said Mathiesen. "We wrote all our shaders from scratch. For textures, we went to a local coffee store and found an old burlap sack that coffee beans had been shipped in. We also went into costume stores and found muslin and different kinds of silk. We wove those together to simulate the very heavy weave of the dementors' robes, while making them float in an airy way, like silk underwater."

Dementors spring into action when Harry grabs the Horcrux from Umbridge, causing Umbridge to summon a protective patronus charm in the form of a cat, while Harry conjures a more abstract effect. RSP generated glowing patronus apparitions, downplaying plasma trails seen in previous films and depicting the spells more as light effects designed to repel dementors.

Harry, Ron and Hermione flee as their polyjuice potions wear off, achieved at RSP as rapid digital transitions between actors. “We did some good old-fashioned morphing,” declared Tim Burke, “and we mixed that up with old-school gags. We had to deal with a height difference with Rupert changing back from his disguise. We got Rupert to go up on his tiptoes, and he acted shrinking back to his original height. We then shot the other actor for a head pass. Rising Sun roto’ed and tracked his head onto Rupert’s body, and morphed that back into Ron.”

The escape from the Ministry turns problematic as Yaxley (Peter Mullan), a Death Eater official, seizes Ron’s arm mid-disapparate. The wizard teleportation effect—known as the ‘chewing gum effect’—expanded on techniques that MPC had developed for the previous film, achieved by filming reference of performers, building digital models of characters and then hand-modeling blend-shapes, akin to stop-motion replacement animation in 3D. For Ron’s injury, MPC deformed digital figures and revealed Ron’s arm painfully stretching in Yaxley’s grip.

Harry and Hermione rematerialize in a glade with Ron, whose arm and shoulder have been ‘splinched.’ David Yates filmed the scene at Leavesden with Rupert Grint wearing a prosthetic makeup. “David referred us to the apparation effect in the sixth movie,” commented Nick Dudman. “That resembled a convoluted Mobius strip of twists and turns, which made me wonder what it would be like if somebody ran up to Ron with a razor-sharp potato peeler and ran it around his shoulder and down his arm while he was being spun through the air 360 degrees.” Dudman’s sculptors arrived at a splinch design that featured furrows a third of an inch deep around Grint’s shoulder and arm. “It was ghastly, and David loved it. We shot variations— less blood, more blood—to give David options. Hermione then uses something called ‘Essence of Dittany’ on the wound, which starts it healing. We did a fresh Dittany version, where the flesh was puckered and healed, but still very angry and pink.”

Hermione uses protective spells to disguise their rural hideout in a tent that is magically larger on the inside. The production filmed tent exteriors in the Scottish Highlands, using greenscreen inserts in the tent flap, allowing visual effects to insert tent interiors shot at Leavesden. Tent interiors, conversely, were backed by greenscreen, allowing insertion of exterior scenic plates. Cinesite handled composites of Harry and his friends at various campsites, including a limestone rock formation in Malham, North Yorkshire. Stuart Craig re-created the Malham site at Leavesden as a 50-foot-square set backed by greenscreen, which Cinesite then integrated into Yorkshire helicopter photography.



Harry determines that the Horcrux, the first of seven artifacts required to bring down Voldemort’s reign, is located beneath the streets of London in the vast headquarters of the Ministry of Magic. Stuart Craig modified the Ministry’s design to reflect Voldemort’s oppressive regime, with monolithic statuary inspired by Soviet Russian propaganda. Rising Sun Pictures created Ministry environment extensions, adapting set extension geometry and textures generated by MPC in previous Potter films, and collaborated with the art department to model the central atrium sculpture, adding upper portions of the monolithic structure and greenscreen crowd enhancements.

The young wizards fail to open the Horcrux, elevating tensions and causing Ron to storm off, leaving Harry and Hermione to continue their quest at Harry's birthplace in Godric's Hollow. Stuart Craig built the main street of the village at Pinewood. John Richardson's team created snow and frost effects using magnesium sulphate underfoot, and biodegradable paper falling snow. Cinesite enhanced falling snow with particle effects, and added environment extensions using still photography shot in Lavenham, Suffolk. "We went to Lavenham mainly to shoot the Guildhall building," said Cinesite 2D supervisor Andy Robinson. "The Guildhall was prominently featured, so we built that in 3D. We also gathered textures to extend the street. When we received the edited sequence, we had a bigger task. Originally, the scene was going to start with the actors further into the set; but they cut into the scene earlier, so all we saw behind them was greenscreen. We rebuilt the set in 3D—with a pub, a church, a wall, and a building with columns to the right—all from scratch. We created geometry, rendered that, did touch-ups and reprojected textures."

Hogwarts professor Bathilda Bagshot (Hazel Douglas) takes Harry and Hermione into her home and transforms into Voldemort's snake, Nagini. The transformation evolved considerably through production. "MPC did some early concept work based on principles of snakes shedding their skin," related Tim Burke. "They used puff pastry textures photographed and mapped onto artwork, which looked quite menacing. After we filmed the scene, we developed the effect further so that Bagshot's skin shriveled, as if she was dehydrating. David's idea was for her head to snap back, her jaw to break open, and Nagini to burst through."

The special effects team provided a wire-rigged wardrobe effect for a practical element of Bagshot's clothes falling to the ground, but the revised transformation required a more extensive digital disintegration. "We animated her body to move like a snake trying to break out of a bag," explained Nicolas Aithadi. "Her entire body went into a frenzy, the head atomized into dust, and then the snake broke out of the clothing. We used a cyberscan, plus photographs of the actress. For the



After infiltrating the Ministry of Magic and seizing the Horcrux, Harry is trapped in an elevator with Hermione and Ron – polyjuice-disguised as Ministry employees Mafalda Hopkirk (Sophie Thompson) and Reg Cattermole (Steffan Rhodri) – and Reg's wife Mary Cattermole (Kate Fleetwood). Harry uses his patronus – generated by Rising Sun – to repel the light-averse dementors pursuing them.



The escape goes awry when a Death Eater grabs Ron in mid-disapparate, causing a painful 'splinch' that tears flesh from Weasley's arm and shoulder. The swirling disapparate effect inspired Nick Dudman to create a splinch makeup for Rupert Grint that suggested helical furrows in the actor's flesh.

motion on the face, we roto-animated the actress, and replaced the body to create the frenzied motion of Nagini inside.”

Before Nagini appears, Hermione discovers Bagshot’s discarded corpse in the woman’s kitchen. Nick Dudman’s key prosthetic makeup artist, Paul Spateri, created the Bagshot likeness using lifecast portions of the elderly performer sculpted to resemble a desiccated corpse. Hermione then runs upstairs, where Nagini corners Harry in a child’s nursery. Dudman’s team provided a full-scale Nagini dummy to help block out the snake action, and John Richardson’s team provided mechanical effects of interactive destruction. MPC then added subtle dust effects to integrate its digital snake, which they lit with environment textures projected onto low-rez geometry of the set.

Harry and Hermione disappear back to their campsite, where Harry later sees a mysterious, glowing patronus doe. David Yates filmed Radcliffe following the doe, using a practical mobile light source on set. “Chris Shaw came up with the idea of what we called the ‘Lightbeast,’” explained Tim Burke. “It was an LED coat that a large wolfhound wore. We had the wolfhound walk around on location at night and it created beautiful interactive lighting in the trees that would have been difficult to animate with our CG doe.” Cinesite digitally painted out the wolfhound and generated a keyframe-animated doe with muscle rigging, fur simulation, naturalistic blinks and twitches, and then created glow effects using 3D volumetrics and Nuke 3D projections.



The Horcrux emanates an oppressive aura that creates emotional tension between Harry and his friends, causing Ron to storm off and abandon Harry with Hermione while they hide out in the English countryside. To simplify the logistics of shooting two films back-to-back, the production kept location shooting close to home, either by using locations within the London area, or by creating backlot sets to represent rural environments. Backlot sets included a portion of a unique limestone rock formation in Malham, North Yorkshire, which Stuart Craig built at Leavesden as a 50-foot set backed by greenscreen.

The patronus leads Harry to a frozen pond, beneath which he finds the Sword of Gryffindor, one of the few weapons capable of destroying a Horcrux. Production filmed Radcliffe entering a water tank buried in a studio set at Pinewood. “We created the frozen pond using a combination of Plexiglas and fiberglass resin textured with cling wrap,” said John Richardson. “We had a second tank offset, so when Dan jumped in and displaced the water, we could keep the water level. We had pumps running all the time, with heaters and filters.” Shots peering into the lake were filmed at Leavesden, where Richardson’s team created two versions of the ice. “We had a Plexiglas and resin rig that actors could stand on for shots looking down at the sword. For underwater views, looking up from beneath the ice, we melted a ton and a half of wax and poured that onto the water surface to create interesting patterns. That formed a 24-by-24-foot sheet, about three quarters of an inch thick.” One of Richardson’s crew members hung at the end of a forklift to pre-cut a hole in the wax sheet for shots of Harry breaking through the ice.

The Horcrux reacts to its proximity to the sword by strangling Harry on its necklace. Radcliffe performed the scene with stunt performers tugging him from the waist. Baseblack then animated the Horcrux as a 3D object that appeared to move with a life of its own. Ron Weasley reappears to

pull Harry and the sword from the water and uses the sword to destroy the Horcrux, triggering a series of supernatural events generated at RSP. “David wanted huge energy to burst out of the Horcrux,” remarked Tim Burke. “It forms a 15-foot-high swirling mass of detritus sucked up from the environment; and then, the different ages of Voldemort push through in a very distorted, creepy kind of way. We did Mova capture with Ralph Fiennes, which gave us some great data that drove the screaming elements of Voldemort’s fragmented soul.”

RSP sequence supervisor Dennis Jones incorporated Mova capture data of Hero Fiennes-Tiffin and Frank Dillane—two actors who had portrayed younger Voldemort in earlier Potter films—with elements generated over an intense period of research and development. “We spent a better part of a year working ideas back and forth,” commented Sean Mathiesen. “We made cloth-like versions of the event. We tried creating meaty organs and elegant oily threads of ink that hung in space, based on effects that we had observed in earlier Potter films. We designed an all-CG Voldemort looking very old and tortured, with sclerosis, vomiting ink. We ended up with a big Houdini effect of a vortex of pond scum and rotten meat and incorporated Mova data into that, with a bit of languid forbidden sexiness designed to bother Ron.”



The production gathered scenic material as second-unit shoots, filmed in the Scottish Highlands and in North Yorkshire, without principal performers. Cinesite spent three days in Yorkshire photographing 360-degree bracketed exposures of the Malham rock formations in various lighting conditions, and then used the scenic textures to build digital cycloramas of the environment. Then they tracked performer plates and blended scenic extensions into scenes, including a helicopter shot that swooped high across the landscape to emphasize Harry’s lonely isolation.

The vortex plays on Ron’s insecurities in his relationship with Hermione, revealing a vision of Harry and Hermione in an amorous embrace, filmed with the two actors against greenscreen on a closed set. “Dan and Emma wore discreet nude-colored underwear,” explained Tim Burke, “which we digitally painted out, suggesting they were naked. Rising Sun then animated a swirling mass of plasma emitted by the lovers, which we intertwined and mixed into their flesh tones and body shapes.”

The Horcrux produces abstract shapes of Ron’s other phobias, producing cascades of inky spider legs mixed with swirling Voldemort visages, rendered in Maya and Houdini and blended in Nuke and Shake. “The Voldemort Mova data was Maya oriented,” Sean Mathiesen said, “but the swirling environmental effects were very Houdini-centric. We did principal compositing in Nuke, using its three-dimensional capabilities to tell Houdini or Maya what to generate, but we also used a few tricks in Shake. It was a very arty and creative way of working, like Jackson Pollock hanging upside down and throwing paint at the walls. If we found a technique that worked, everybody hung upside down and threw paint at the wall!”

Ron destroys the Horcrux and rejoins Harry and Hermione to visit the home of the eccentric Xenophilius Lovegood (Rhys Ifans), father of an imprisoned ally, who shares insights into Voldemort’s agenda. Stuart Craig designed Lovegood’s home as a crooked stone tower in the English countryside. Double Negative shot scenic plates for the environment at Grassington, in Yorkshire.

The production built the lower portion of Lovegood's home at Leavesden. Double Negative shot photographic surveys of the set and generated a digital environment, extending the tower and placing it in the bucolic setting.

Inside the wizard's home, Lovegood operates a ramshackle printing press cranking out anti-Voldemort Quibbler pamphlets. The special effects team built the printing press as a practical contraption with working rollers. "They wanted to see Quibbler papers running through the set," said John Richardson. "I knew if we tried to do that for real we'd get a very limited number of takes before we'd have to stop and reset. Instead, we rigged a number of endless belts. They ran across the set at right angles and then went into a little end piece where the papers shunted out at speed. We built it so that we could load about 200 sheets of paper and it could run continually all day long."

Lovegood points Hermione to a story in her fairytale book, *The Tales of Beedle the Bard*, and listens as she relates a wizard folktale about three enchanted artifacts —'Deathly Hallows'—that grant their owners dominion over Death. To dramatize the story, accompanying Emma Watson's narration, Double Negative generated a transition into an animated sequence created at Framestore's commercials division based on the stop-motion animation of Lotte Reiniger. "Stuart Craig suggested the Lotte Reiniger reference," said Tim Burke. "It was beautiful animation created using 2D cutouts. Animation director Ben Hibon developed his own interpretation of that technique in a stunning three-minute sequence. He used 3D to create characters that appeared to have depth, yet they had a flat 2D quality, like Indian shadow puppets."

Framestore sequence supervisor Dale Newton collaborated with Hibon to generate Beedle the Bard characters in Maya, emulating the rigidity and motion of Reiniger's hand-cut paper silhouettes. Backgrounds were based on digital photographic textures of backlit paper, layered to create depth and translucency. "The characters appeared to be embedded in a fog of layers of paper," said Christian Manz. "That gave the scene depth, as if the figures were casting shadows on the paper. There were rivers, trees and meadows, and a beautiful sequence with a bride in her wedding dress that looked like it was made of backlit paper. There



Seeking more clues to the mystery of the Horcrux, Harry and Hermione visit Harry's birthplace of Godric's Hollow, where they encounter Bathilda Bagshot (Hazel Douglas), a Hogwarts professor possessed by an evil spell, who transforms horrifically. MPC generated Bagshot's transformation using cyberscans of the actress to generate the woman's shriveling body.



Voldemort's giant snake, Nagini, bursts out of Bagshot's withered body and attacks Harry. John Richardson's team provided on-set interactions of smashing furniture. MPC added the CG snake, lit with environment textures projected onto low-rez geometry of the set, and added subtle dust effects to integrate the creature.

were cloth simulations, simulations for swirling leaves and flocking birds—40 or 50 of them, all hand-animated along paths. Two compositors then created the final look by bringing together the mental ray renders and layering them in Nuke.”

After Hermione finishes her tale, Death Eaters attack Lovegood’s home, obliterating it. John Richardson’s team rigged the Lovegood set with approximately 200 squib hits simulating violent destructive blasts from Death Eater wands. Double Negative generated Death Eaters as torpedo-like smoke plumes that barnstorm the house. “It was like a *World War II* air attack,” commented David Vickery. “We extended the environment and the house, but the bulk of our work was choreographing the Death Eaters. David Yates wanted them to be circling; but when we blocked in all the spell hits, it very quickly became confusing.” Double Negative’s animation team rescaled the assault to incorporate fewer wand hits with greater percussive hits. “We used our rigid body simulator dnDynamite and our fluid simulator Squirt and took the house to pieces in about 20 seconds.”



Harry is reunited with Ron in a forest glade, where they succeed in opening the Horcrux, unleashing a powerful malevolent force that fights for its survival as a dislocated fragment of Voldemort’s evil soul. The production filmed the Horcrux eruption in a forest set built at Leavesden. Rising Sun Pictures provided digital set extensions to enhance the depth of the forest, and spent nearly a year developing the Horcrux eruption as a complex blend of swirling forest detritus, inky smoke effects, amorphous fleshy objects and facial capture elements of Voldemort in his child, adolescent and adult forms.

Harry, Ron and Hermione disappear just before a Death Eater spell hits a highly unstable exotic plant in Lovegood’s home, destroying the house. John Richardson’s team detonated squibs plus a cascade of Quibbler pages as destruction aftermath. Double Negative then reverse-engineered the explosion. “We built a CG model of the destroyed house,” said Vickery. “Our effects artists referenced footage of crumbling smoke stacks and applied that style of destruction. We used a Dynamite rigid body simulator as the center of the house exploded, and Squirt to re-create dust and smoke. Then we added flying glass shards as Maya particles, and remnants of papers that tied in with the practical effect.” The camera then pulls away from Lovegood in a high-angle shot revealing small gas-filled succulent fruit—dirigible plums—that are dislodged by the explosion and become airborne. “We animated dirigible plums partly as keyframe animation, partly as a dynamic simulation as the plums twirled in vortices behind a Death Eater.”

The threesome escapes the Death Eaters, but runs afoul of a group of mercenary Snatchers in league with Voldemort. The creature effects team furnished a prosthetic makeup for Snatcher leader Fenrir Greyback (Dave Legeno), a thuggish werewolf reverted to animalistic form. “In the sixth film, we created a very subtle makeup for Fenrir,” observed Nick Dudman. “We used animal fur punched into platgel appliances that went down to his waist. David Yates suggested that, in the intervening year, Greyback had lost the ability to revert to human. So this time we took the appliances right across the actor’s face, made his fur very greasy and gave him dreadlocks.”

Baseblack generated wand effects for the Snatcher chase, and Framestore and Nick Dudman created effects of a stinging jinx, which Hermione casts on Harry to disguise his appearance. “We had to disguise Harry so it was believable that the Snatchers might not recognize him for a period of time,” explained Dudman. “Our concept artist, Martin Rezard, initiated the design in Photoshop and ZBrush using photos of Dan Radcliffe, and then sculpted a three-stage swollen-face makeup. Stage One covered Dan’s face apart from one eyelid. Stage Two covered nearly half the face, so Dan was recognizable from certain angles, but one eye was still closed. Stage Three showed just remnants of disfigurement. We produced those all in platgel, and Stephen Murphy applied the makeups with Paula Eden. Paula hand-punched eyebrows and beard stubble, so David Yates could get the camera as close as he liked.” Dudman’s team provided Framestore with rigid castings of prosthetics for scanning, to help tracking of Radcliffe’s face during makeup stage transitions.

Greyback hauls Harry, Ron and Hermione to Malfoy Manor, which is now seen with bare winter trees—shot day-for-night, re-graded to moonlight, with sky replacements and environment extensions generated at RSP. Voldemort’s lead Death Eater, Bellatrix Lestrange (Helena Bonham Carter), throws the captives into the cellar and attempts to confirm Harry’s identity before summoning Voldemort. Baseblack created Bellatrix’s wand effects, including leather whip and snake that fasten around their victims’ necks.

In the cellar, Ron uses his deluminator to generate spheres of light that illuminate the room revealing other prisoners, including Griphook (Warwick Davis), a renegade goblin glimpsed as a supporting character in earlier Potter films. “Griphook had a lot of performing to do this time,” noted Nick Dudman. “We gave him black contact lenses, teeth, nails, and quite a heavy multi-piece platgel makeup, with major ears and nose.” Griphook’s nose required a reinforced core, created by pouring a denser platgel mix into the mold. After cleanup and painting, prosthetics were hand-punched with eyebrows and hairlines. “The very first day we put the wig on Warwick, Katy Fray and I applied the makeup, looked at it, and thought, ‘Wouldn’t it be nice if the hairline came a little bit further forward?’ So Katy, who has no fear, took a needle and, one hair at a time, she punched hair into the makeup while Warwick kept very, very still.”

While Bellatrix tortures Hermione, Dobby apparates into the cellar to rescue Harry and his friends. Framestore animated Dobby and used Houdini and Nuke to create wand effects as Harry duels with Bellatrix and the Death Eaters. Dobby enables Harry’s escape by causing a chandelier to fall from the ceiling. John Richardson’s team rigged the chandelier fall as a practical effect. Ron and Harry then disappearate in slow motion with Hermione and Griphook as they see Bellatrix throw a knife,



The eccentric wizard Xenophilius Lovegood (Rhys Ifans) counsels Harry and his friends in his country home and then rails against an airborne Death Eater attack. Stuart Craig constructed the lower portion of Lovegood’s home and its environs on the Leavesden backlot. Double Negative integrated the set into scenic textures of a rural landscape and generated Death Eaters as smoke plumes animated in the studio’s fluid simulation engine. Stuart Craig dressed Lovegood’s garden set with gas-filled fruit, known as ‘dirigible plums,’ which Double Negative animated in the closing moments of the scene as severed plums drift skyward.

which strikes Dobby. Framestore developed the slow-motion disapparate effect using digital retimes on slow-motion footage, combined with fluid simulations and effects animation.

Harry and his friends escape to Bill's and Fleur's beachfront house, Shell Cottage, where a heartbreaking scene plays out as Harry cradles Dobby in his arms and the brave little house elf dies. The production built the façade of Shell Cottage on location in Wales. To film Dobby's death, Toby Jones joined the company on location and performed the scene with Daniel Radcliffe. Radcliffe then repeated the scene with a Dobby size-double. "It was a wild shooting day," recalled Tim Burke. "We were filming on the beach, the wind was blowing, the tide was coming in, and we had two hours to get all the shots. We captured Toby on HD right there, when everyone was in the moment. Then we shot Toby again later, with HD cameras set up in our hotel. For Dobby's interactions, we used our little person size-double because Harry had to catch Dobby as he fell."

The creature effects team also provided a weighted, loose-jointed dead Dobby dummy adapted from the original maquette. "We made a beautiful skeletonized Dobby," said Nick Dudman. "It was completely floppy, with fully rotating wrists and individual finger movement. We poured it in a solid, very soft platgel, and it just felt real."

The dummy and the body double became lighting reference for Framestore while integrating the animated character into Radcliffe's arms. "Tim shot a lot of reference and clean plates," said Christian Kaestner, "but the takes that David Yates chose were the ones of Harry interacting with the stunt double. That required a lot of paintwork, so we went to Leavesden and shot texture reference of Harry's wardrobe and Daniel's hands, and we used those textures to rebuild parts of Harry that the double had obscured. We then restored areas of Dan's jacket, his shirt and hands by reprojecting and animating textures."

Toby Jones' reference video provided the basis for Dobby's facial performance. "Toby gave us a lot to



Harry escapes the Death Eater attack on Lovegood's home and runs into a band of mercenary 'Snatchers' led by a werewolf, Fenrir Greyback (Dave Legeno). Nick Dudman's team reprised a makeup devised for Greyback in the previous Potter film and gave the character a more animalistic appearance, with extended prosthetic coverage and greasy dreadlocks. Key prosthetic makeup artist Katy Fray details Greyback's makeup.



Dudman's team also created a new and highly expressive platgel silicone prosthetic makeup for Griphook (Warwick Davis), a goblin that Harry encounters after Greyback imprisons him at Malfoy Manor.

refer to, particularly with the mouth,” said Pablo Grillo. “We had to make our own interpretation of Dobby’s eyes, because they were so much larger than Toby’s, but a lot of the power of Dobby’s death came from the way David Yates shot it. It was very gritty, with a lot of free camera movement.” Framestore made Dobby’s eyes appear watery and, as the house elf expired, desaturated skin textures to make him wan and pale. Daniel Radcliffe then performed the burial using the Dobby dummy wrapped in a sheet.

Back at Hogwarts, Voldemort retrieves the powerful Elder Wand—one of the Deathly Hallows—from the hands of Dumbledore’s corpse in a tomb on an island in the ancient school’s Black Lake. “The scene began with a helicopter shot coming in over the lake,” related Matt Twyford. “We inserted a photographic element of an island from another lake.” Voldemort opens Dumbledore’s tomb with a spell that splits the marble, achieved as a 2D animation effect, which reveals a matte painting of a shattered tomb.

Standing over Dumbledore’s tomb, Voldemort raises the Elder Wand and unleashes a spell into the sky. The production shot separate motion control elements, months apart, of Voldemort, Dumbledore and the broken tomb. Baseblack CG supervisor Fredrik Sundqvist and his team created a 3D environment for the scene, which senior compositor Rudi Holzapfel then blended with filmed elements. For a final shot of Voldemort wielding the wand, 2D lead Adrian Banton integrated animated 3D lighting elements with a still plate of the island surrounded by volumetric CG clouds and a matte painting of the wider environment, closing out the film.

The production announced the completion of principal photography for the *Harry Potter* film franchise in June 2010. However, although the main unit had wrapped, work for special effects, makeup effects and visual effects resumed with ten weeks of second-unit shooting for *Deathly Hallows: Part Two* during the final weeks of postproduction for *Part One*. “We’ve got a big shoot coming up very soon,” said Tim Burke, “and we are heavily involved with the development of some very exciting sequences. I must say, the best is yet to come.”

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In the closing moments of the film, Voldemort seizes a powerful magical talisman, the Elder Wand, from the tomb of Albus Dumbledore – on an island in the Black Lake at Hogwarts School of Witchcraft and Wizardry – and unleashes a powerful spell into the night sky. Baseblack generated the environment using disparate elements filmed over many months. Scenic elements included an island and a lake from two separate locations, a model of Dumbledore’s tomb, greenscreen elements of the two performers, 2D and 3D volumetric lighting effects blended into volumetric clouds, and a matte painting of the wider environment.

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